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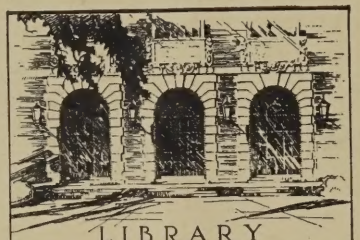

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REDTENBACHER'S MEDIAEVAL ARCHITECTURE.

SECTION 1. DEVELOPMENT OF MEDIAEVAL ARCHITECTURE.

1. Relation of Mediaeval to Antique and Renaissance Architecture.

As Antique architecture was chiefly developed in the Temple, so was Early Christian and Mediaeval architecture principally worked out in the Church, in contrast with Renaissance architecture, which depended upon the Palace more than on its Churches. But while the Antique only created small rooms with horizontal ceilings in the Greek temple, or spacious vaulted structures in Roman baths, only by using great quantities of building materials, Early Christian, Mediaeval, and Renaissance architecture errected spacious vaulted churches with a relatively small amount of building materials. Architectural construction in the Antique moved within a narrow circle, although it succeeded in making the noblest disposition of the space; Early Christian art employed nearly the same construction as the Antique, but applied it to the new problems proposed by Christianity. It really invented nothing in construction, leaving this to the middle ages. Neither was the Renaissance creative in this field, for its work lay elsewhere, although erecting the largest domed structures ever built.

In the artistic decoration of buildings, neither Antique nor Early Christian architecture clearly decided to make construction the beginning point of decoration; this remained for Mediaeval architecture, which first rose to the idea of applying ornament where construction afforded oppurtunity, thus imparting to this an expression of form exceeding absolute necessity. Although it may not be stated that neither Antique nor Renaissance did this, yet mediaeval architecture did this most consistently, if not most completely. Thus it absolutely freed itself in construction and decoration from every tradition of the past and sought its own methods. At its best, mediaeval architecture recalls almost nothing of antiquity, to which it primarily owes the means of its creations; what was taken from the Antique was not received directly , like the Renaissance, but indirectly and from Early Christian art.

2. Basilicas in Early Christian Art.

After fixing forms of divine worship, Early Christian art likewise fixed and developed the ground plan of the church. The most important types of plan were those of the Latin cross, the Greek cross, and the central plan. The basilica in form of a Latin cross were treated as follows: The nave was occupied by believers, in larger plans being divided into 3 or 5 aisles by rows of columns; the middle aisle ended at the east in the semicircular apse containing the altar, the throne of the bishop, and the seat of the priests. A transverseaisle for use by the clergy was sometimes inserted between nave and apse, and before the western end was usually placed a court enclosed by porticos. This form of plan prevailed during the entire middle ages; towers were at first

unkown in Early Christian art, being first employed after the 7th century, free and detached from the church. Early Christian basilicas were covered by ceilings with wooden beams, the apse alone being vaulted by a half dome.

3. Section of Basilica.

Beams were laid on the colymns or on the arches turned between them, which support the clearstory wall of the middle aisle. Windows were pierced in the clearstory walls above the roofs of the side aisles. These designs with 3 or more aisles and with clearstory windows are termed basilicas, as a distinction from hall churches with aisles of equal height, and from churches with a higher central aisle without clearstory windows. The Early Christian basilica usually has a horizontal ceiling, but the principal mediaeval basilicas are vaulted.

4. Greek Cross Plan.

In the Byzantine empire, founded by transfer of the capital to Constantinople in 330, was developed Byzantine art, whose principal achievement in architecture eas the domed structure. The Greek cross type with equal arms was embodied in a series of churches with nine squares on the plan covered by domes, eight of these being grouped around a central square enclosed by four piers. Circular arches connect the piers and extend to the walls, upon their crowns resting the domes. The interspaces between domes and the supporting arches, the so-called pendentives, were built in horizontal courses or were themselves vaulted. The dome with its pendentives is called a pendentive dome. Only when four arches about the central square supported between the pedentives and the dome a cylinder or drum, pierced by windows, may we say that the Greek cross plan attained its highest point.

5. Central Buildings.

Central buildings in Early Christian architecture are circular or rarely polygonal plans, consisting of an inner circle of columns or piers and one or two concentric aisles, all of equal height as in hall churches, with a higher central aisle, like basilicas with a central raised structure lighted by clearstory windows. These central buildings either have horizontal ceilings, like the great 5-aisled Church of S. Stefano Rotondo in Rome, or are vaulted, like S. Vitale at Ravenna.

6. Inherited Portion of Mediaeval Architecture.

The inherited elements in mediaeval architecture are the Roman vaults, such as tunnel vaults, groin vaults, and dome, whose highest triumphs are found in the baths, and also the most important forms of Early Christian church, the pavilion type of plan, the Greek cross plan, magnificently executed in the Church of Mark at Venice, and the central structure, best represented by S. Lorenzo at Milan, and at Ravenna.

In regard to form of cross section of the Church, three types were in use: the hall structure with aisles of equal height, the 3-aisled structure with a higher central aisle and without clearstory windows, and the basilican design with clearstory windows. On the combination and development of these motives depends the entire system of mediaeval architecture as developed in the various countries of Central Europe.

7. Individuality of Mediaeval Architecture.

Mediaeval Architecture inherited the acquirements of its precursors in construction and plan, but transposed and developed this inheritance. It s construction and its plans were usually quite different and novel. Although retaining the typical idea of supports for horizontal beams and plane ceilings or arches and vaults, these supports were of quite different form although it adopted in the decoration of its works the generally valid ideas of free-ending, of subdivision of separated and combination of connested parts, of bordering and enclosing openings, of characterizing and accenting individual parts, of transfer of related though diverse parts, of unity in variety and variety in umity, etc., likewise the basis of the use of form in the Antique, yet it produced own individual treatment, peculiar to itself alone. For it solved an esthetic problem, which its precursors scarcely recognized or could not master, that of making the vertical axsis of the building dominant, which appears in every detail, subordinating the horizontal so far as necessary, and allowing it as if suggested in certain portions of the organic structural mass. Better than other architectural styleak it understood how to indicate even in the substructure what was to be developed in the upper parts. While all styles of the past and future are characterized by a simple and plain treatment of the masses, mediaeval architecture first understood how to produce effect in the richest and most costly structures by a difference in proportions, and by treatment of the whole, and of the separate masses, in harmony with the whole from every point of view.

Mediaeval Architecture is more than any other peculiar in its creations; in spite of general rules fixing its type, a peculiar artistic nature is found in all its works, ever striving after new ideas, according to a knowledge of things already accomplished, although often at the expense of artistic value. Only with a superficial knowledge of mediaeval architecture can one decide, that the individual first makes himself felt in the Renaissance; the Renaissance made a certain progress in words, names and books, compared with the middle ages, but not at all in architecture.

8. Methoñ of the Artistic Creation in Mediaeval Architecture.

According to development of the style at the time, mediaeval architecture always methodically treated in its designs existing problems and the means or

vailable for their solution, basing everything on the problem itself. For example, if about the year 1200 a church were to be built in the Rhine provinces, its size being fixed by the number of attendants, the architect reasoned as follows:-- the nave of the church must be large enough to contain all attendants at church; a plan with 3 aisles would suffice for this purpose. For extension of divine service on festivals, a special room is required, and I will add transepts to project at each side of the church. For the clergy, will be required separate choir at the rast. Since two altars are necessary in addition to the high altar, I will place two side apses beside the choir apse on the east side of the transepts. To separate women from men during divine service, I will arrange galleries over the side aisles. These will require on the west facade two towers with stairways, whose upper portions will form bell towers. These towers include between them a vestibule below and an organ gallery above. Between the choir and the side apses, I will arrange staircase towers to give access to the roof of the choir, lower than that of the church. The church will be sufficiently large if I make the middle aisle 50 ft., and each side aisle 25 ft. wide. Since I wish to cover the church with square groin vaults, I shall have three full squares for the middle aisle, and six squares for each side aisle, whose sides are half those of the large squares. I shall need large piers for the large vaults and lighter ones for the smaller vaults. To each tower on the west facade, I will assign the internal space of one square of the side aisle. Their thicker walls must therefore project beyond the sides of the church. The organ gallery may then receive the space of two small squares. Its front wall requires less thickness than those of the towers, so that the towers will project beyond it. I will make the transverse aisle the same length as the middle aisle, and it will therefore project on each side of the nave about a side of a small square. The ground plan therefore results entirely from a logical process of reasoning. The same is true in working-out the longitudinal and cross sections, as well as the external appearance of the church.

I must connect the piers by arches on which will rest the vaults. Above the side aisles are to be galleries, which will open into the central aisle by wide openings. Since I wish to make these as low as possible to save materials, and not waste space, their arches next the middle aisle will form a continuous series of relatively low openings, to be divided by small columns. Where the roofs of the side aisles abut against the clearstory walls of the middle aisle, I can have on the inside either large wall spaces for paintings, or a continuous triforium composed of a series of small columns and arches. Above this triforium will commence the great vaults over the

middle aisle. I shall place windows in the clearstory walls. Thus I shall produce a groin-vaulted basilica with galleries and an internal passage, the so-called triforium.

The exterior of each bay of the church also results naturally. The side aisles require windows, and the galleries may be lighted by round windows. I will separate the different bays by pilasters, and the side aisles from the galleries by a belt-courseo I will connect together the pilasters below the cornices by a round-arch frieze. I will likewise divide the clearstory pilasters, as well as the transverse aisle. On the main facade, I will use a large portal, and place a great window in the organ gallery. Corresponding to the roof of the middle aisle, I will crown the facade by a gable, in which I will pierce a round window to light the attic. I will treat the transept facades like the principal facade, The towers are entered from the vestibule and require stairs to the attic with small windows for lighting. Above the attic, I will provide a story for various purposes, above this being the open belfry. I will arrange a gallery at the base of the spire. The small apses of the transverse aisle need no windows and will be decorated by pulasters. I will light the large choir apse by two or three windows, and arrange a low external gallery above its vaults to connect the two choir stair-case towers.

This logical process occurs in all designs in mediaeval architecture. It never collected pleasing motives from different buildings and fused them together; on the contrary, it rejected every element not deduced from the problem by natural evolution. On this depends the harmony of all mediaeval buildings, for they were ddsigned in accordance with the plan and were not fanciful combinations.

9. Principal Periods of Mediaeval Architecture.

The transition from Early Christian to Mediaeval Architecture is formed by the Carlovingian period, on that of Charlemange (768-814) and of his successors, the 9th Century. The best period of the middle ages is that of the Crusades, from the beginning of the 1st in 1096 until the close of the 7th crusade in 1291, or from the end of the 11th to the end of the 13th Century. Before the middle of the 13th Century, architecture was almost entirely in the hands of the clergy, being afterwards controlled by the laity. The Carlovingian period determines the entire course of mediaeval history as well as the development of architecture. First examine this historical period.

10. Charlemange.

Charlemange was the true founder of mediaeval customs and culture, a broad-minded genius, who united all primitive Germanic peoples, and intended to restore the ancient Roman empire on the German soil; under him, Roman, Byzantine, and partly Mohammedan culture influences combined with German character.

Charlemange's empire comprised France, Germany, Italy, and thus Central Europe; excluding border races and kingdoms, Slavic peoples, also Spain and England, inhabited by Anglo-Saxons, Irenians, Picts, and Scots; also excluding Denmark and Sweden, the kingdom of the Avars, comprising the greater part of Hungary, Bulgarians, Servians, and the Byzantine empire, which in addition to Turkey in Europe included Greece, Asia Minor, Dalmatia, and southern Italy from Naples to Sicily. On this form of the Carlovingian empire chiefly depends the entire evolution of mediaeval architecture; it is primarily Christian by the problem set for it by Christianity, then German-Roman from the combination of different national elements, with due consideration of Byzantine and Mohammedan influences.

Charlemange desired to found another Rome at Aix-la-Chapelle, and his architectural tendency was to a kind of Proto-Renaissance, based directly on the study of Vitruvius. But Mohammedan elements also affected Carlovingian architecture; when Charlemange conquered a part of Spain in 778, Moorish art was already at its best; the Mosque at Cordova was begun in 786, completed in 965, and contained ideas, that could very properly be transferred to Christian architecture.

In this early period, the pointed arch first occurred in France; as a structural arch, it is earliest found in the Mosque of Amrou in Cairo, built in 640, from the 8th Century, it was already in use as the section of the tunnel vaults of the Churches in southern France. The diagonal arrangement is a motive first found in Charlemange's Cathedral at Aix-la-Chapelle, except in Mohammedan buildings, and it plays the most important part in Mediaeval architecture. Assuming a square to be described on each side of an octagon, and joining their angles, we obtain a polygon of 16 sides, with triangular spaces between the squares. The plan of the Cathedral at Aix-la-Chapelle is thus formed, (Fig. 3). The triangular bays of this outer aisle are covered in the lower story by triangular groin vaults, a motive previously found only in Moorish buildings. But this ground plan at Aix-la-Chapelle already contained the germ idea of the choir-ending of Gothic cathedrals, and essentially differed from the plans of the Church at Ottmarsheim in Alsace (Fig. 1), and of S. Vitale at Ravenna (Fig. 2), which correspond to the two concentric octagons. The old Cathedral at Brescia probably served as a model for the Cathedral at Aix-la-Chapelle, from which it differs only by its external circular form; at Malcesine on Lake Garda, Charlemange had a castle, and could therefore easily have known this building, erected in the 7th Century, according to Hubsch. The primary model for these and all similar central buildings of the early middle ages may have been the Chapel of the Holy Sepulchre at Jerusalem, built by Constantine 326 to 335.

We therefore see that even under Charlemange, these important motives of

truly mediaeval architecture occur; the pointed arch, the diagonal arrangement, and the triangular groin vault.

11. Post Carlovingian Period.

Charlemange's grandsons Lothair, Louis, and Charles, destroyed his work of union by the partition treaty of Verdun (843), the origin of the German and French nations. Thereafter three national groups existed, the Gallic, Germanic, and Lombardic.

Lothair received the kingdom of Italy, excepting Naples and southern Italy, Burgundy and the countries on the left bank of the Rhine in central Germany, so that thenceforth a continuous line from Italy through Switzerland and along the Rhine divided Europe into western and eastern portions; Louis united with his Bavarian duchy the German-Frankish provinces; a part of the Avars and Pannonia, Allemania, Friesland and Saxony; besides his inherited Acquitania, Charles obtained the Spanish Mark, western France, Brittany, Flanders, and also western burgundy. The three countries, France, Germany, and Italy, from their beginning not only took in charge all further culture, were not merely the chief makers of history, but they also became the early seats of art, and especially of architecture, divided into the French, German, and Italian or rather Lombardic , architectural groups. All the provinces of Lothair's kingdom had in the middle ages something common in their architecture, the prevailing Roman type of the basilica with horizontal ceiling, later groin-vaulted.

The provinces and peoples of the kingdom of Louis approximated in their architecture the general type of the buildings in Lothair's kingdom, but sometimes developed the basilica with horizontal ceilings or with vaults independently, sometimes in accordance with the people of Burgundy.. The Rhine provinces, by their commercial advantages, and Saxony, prominent under the Saxon emperors, played the chief parts. France adjoined Lothair's kingdom and Spain, and was quite different from the two kingdoms just mentioned: it was especially affected in the south and west by Byzantine influences from its maritime relations with Venice and Constantinople, in the southwest by Moorish-Spanish influences, and in the north by a Norman-Anglo-Saxon coloring.

This is explained by the following reasons. Before Charlemange, central Italy and Lombardy scarcely contained any but Roman and Early Christian buildings, and the Byzantine empire possessed almost exclusively domed churches on the plan of the Greek cross. Besides many Roman castles and isolated Roman baths in Germany, the cities of Treves, Cologne, Mentz, Strasburg and Regensburg were especially rich in Roman buildings, like Provence, Auvergne, and Burgundy in France. The cities of Arles, Nimes, Orange, Aix, Avignon, Autun, and Carcassone, there remained important Roman buildings, then used for ecclesiastical, secular and military purposes. All these Roman buildings exerted

decided influence on mediaeval architecture in their vicinity, not affecting the general character of the different structures, but the treatment of their details.

The reason why Byzantine influences appeared in western France, and especially in Acquitania, was that all communications between Venice, as the intermediary of all commerce with the east, and northern France, passed along the main route through western France, to avoid the long voyage around Spain and passing the Straights of Gibraltar, then made unsafe by Arab pirates. The maritime traffic with the East found safe ports at Marseilles and Narbonne, whence its goods were carried beyond Limoges, the seat of an ancient Venetian colony, to Nantes or Rochelle, and even to Brittany, Normandy and England. The arrival of the Venetians at Limoges in 988 or 989 decided the coloring of the entire civilization of western France; from thence the merchants sent in all directions their spices, ornaments, rugs and fabrics. The important Abbey of Periguex was founded shortly before, whose church exhibits in its plan so many similarities to the Church of S. Mark at Venice, like that, being covered by domes over square bays, the pendentive dome; this was the model for a series of some 40 churches in central and western France.

The Normans were a warlike and active race, filled with energy and desire to learn, not influenced by Roman civilization, but accepting Christianity, and besides the Roman and Byzantine elements of civilization, they formed the third factor, which aided in determining the architecture of France. Their peculiarities were their practical bent, appreciating the economic advantages of durable construction, a desire for fame impelling them to the founding of permanent monuments, a love of splendor and lavishness for pride, a knightly pride with the old northern rudeness and hardness, yet with this was joined a receptivity for religious feeling, causing an energetic acceptance of Christianity.

The great province of Neustria around Paris, also termed Francia, understood how to unite architectural elements from the countries already mentioned, under the influence of Burgundy and Austrasia (eastern France with Belgium, Lothringia, and countries on the right bank of the Rhine), in building the Abbey of S. Denis, thereby creating the Gothic style, the name of Romanesque being applied to mediaeval architecture preceding this. The period from 1000 to 1144, the date of the founding of the Abbey of S. Denis, is that of the Romanesque style in France, and from 1144 till about 1227 is that in which the Gothic style attained its climax. Although during this period some details of the new style of architecture penetrated into Germany, and gave a peculiar tinge to the Romanesque style used there, producing the so-called German transition style, the ground was prepared for the appearance of the earliest German Gothic building, the Liebfrauen Church at Treves, commenced in 1227.

To avoud misunderstanding, it must be here stated that the Romanesque style in nowise ended at the introduction of Gothic at S. Denis and at Treves, but the new tendency, like a religious faith, had to gradually conquer its ground. Germany was always inclined to decentrilazation, and took a peculiar part in the evolution of mediaeval architecture; it was most important in the transmission of both civilization and art to the eastern provinces of Europe.

12. Middle Ages Proper.

From the Carlovingians to the Crusades is the period of consolidation of three great western kingdoms. After the end of the Carlovingians, the Capets ruled in France from 987 till 1328, being named after their first king, Hugo Capet. Instead of the series of Carlovingian princes in Germany ending in 911, the Saxon imperial house succeeded in 919, followed by the Salic emperors from 1024 till 1125, and by the Hohenstaufens from 1138 till 1254. After the Carlovingians, two powers controlled Italy, the Roman-German empire till 1056 and the Papacy soon afterwards. Under Charlemange, the Pope was merely the "First Bishop of France", the Papacy only becoming independent after his death. The secular authority of the Pope was established under Gregory VII (died 1085) by the subjugation of Henry IV at Canossa. The period from 1056 till 1254, the end of the Hohenstaufens, is that of the contest between papacy and kingdom. Urban II originated the Crusades, carried out by his successors. This is an outline of the historical background of the architectural history of the early middle ages; a new love of life and "willing sacrifice" in favor of the church was awakened by fear of the year 1000, predicted to be the end of the world. The ruinous ancient churches were rebuilt, and innumerous churches and monasteries were founded. Cities gradually prospered, and since their wealth, with that of the princes and that of the church increased during the Crusades by the extension of the commerce of the nations, they aroused a peculiarly religious inspiration, and made it possible to strengthen Germany, Italy, France, and England, while these employed their power externally.

The architecture of the Gallic peoples, divided into many races, evolved different types of architecture in accordance with its coloring by Roman, Byzantine, and Norman influences, whose combination in consequence of the general rise in civilization during the period of the Crusades occurred about the middle of the 12th Century, in the vicinity of Paris.

Germany differs from France by greater conformity in architecturek not there divided into types of architecture, but like different dialects, it varies according to the derivation of the people. The basilica with horizontal ceiling or groin vaults prevails everywhere in Germany, the zntique coloring of the monuments fades, and BYzantine influences are scarcely visible. But the tunnel vault and dome long continued in use in France. At a very early date, a chief

motive of Gothic appears in the ground plan, the aisle around the apse with a series of chapels (Fig. 4), contrasting in Germany with the idea of the church with double choirs (Fig. 5) and with the triapsal plan (Fig. 6). Before the 12th Century, Germany was especially influenced by Lombardy, afterwards by France.

Lombardy chiefly adheres to Roman-Early Christian church architecture, is allied with Germany, but was politically independent from the 10th to the 13th Century. As elsewhere in Italy, Lombardy is characterized by the use of costly building materials, marble columns and mosaics, a preference for decorative coverings for walls, neglect of consistent and complete construction, with the resulting use of unstructural expedients.

13. Religious Orders.

The clergy, especially monks, engaged in improving and extending mediaeval architecture until in the 13th Century; the laity chiefly cultivated architecture afterwards, were originally educated in monasteries, but later became independent architects, who worked in common in fraternal societies, similar to workmen's lodges. This results in the first half of the middle ages from the ecclesiastical buildings and cloisters, as well as the care of the arts and sciences connected therewith, chief duties of the clergy, after their fulfilment in later times less important than other aims of the church. The rise of cities and the increased strength of communities brought to architects in the later middle ages a series of great problems, whose solution required united skill.

Among religious orders, the Benedictines played an especially important part; the first minastery in the west was founded by S. Benedictine in 529 on Monte Cassino in Campania, and placed under the rules of the Order. From this date until the Council of Constance (1005), the Benedictine Order founded 5070 monasteries and furnished 24 popes, 200 cardinals, 400 archbishops, and 7000 bishops. Monasteries and monks fell into great decadance during the 11th and 12 Centuries and needed reforms.

The Benedictine Order was regenerated by the abbots of Cluny (founded 909) in accordance with the rule of the Monastery of Citeaux near Dijon, founded 1098 by the Benedictine abbot Robert for severer asceticism. A Number of monasteries became subject to Citeaux, and the Cistercians were diligent in establishing monasteries on the model of the parent Monastery at Citeaux. The most important Benedictine monasteries were at Tours, S.Gall, Fulda, Weissenburg in Alsace, and Corvey in Westphalia; they were nurseries of culture and schools of development. The Cluniacs receivef from their parrent abbey at Cluny the work of the education of man, and Cistercians also in Germany, as successors of the Benedictines. In the 12th Century, the brotherhood of Cluniacs counted over 200.0 monasteries, and there still remain in Germany about 100 prominent monasteries

of Cistercians from this and the next period. The other orders, Carthusians, named from the Chapter-House of Bruno of Cologne near Grenoble, and the Premonstrants, deriving their name from the parent monastery of Premontre near Laon, were of less importance during this period.

The so-called Mendicant Orders were founded in the 13th Century, rejected all earthly possessions in faithful imitation of Christ, and Franciscans, Dominicans and Minorites first exerted a decided influence on the Gothic style. We shall consider the activity of the monastic orders more fully. To the Benedictines are due the abbey churches with double choirs, already represented in the 9th Century in the famous parchment plan of S.Gaul, and a faithful copy of these plans is found in Cathedral chapters and their cloisters connected with bishop's palaces, as well as collegiate foundations originating in the 10 th Century.

The monastery plans of the Cistercians were developed from the parent churches at Citeaux and Fontenay and have rectangular choirs; with an aisle around the choir in accordance with the first example, are the monastic churches at Riddagshausen, Brunswick, and Ebrach near Bamberg (Fig. 7); without an aisle like the second model, but with several choir chapels, are many monasteries in Germany, like Loccum (Fig. 8) in lower Saxony, and Malbrunn in Wurtemburg.

The chacteristics for the Cistercian Order are simple arrangement and omission of the towers; monasteries are usually extensive designs, like those of the Benedictines.

The monasteries of the Mendicant Friars, (Fig. 9) are less extended plans, even simpler than those mentioned, and they lack the transverse aisle as well as the bell towers. Allied to them are the hermitage monasteries of the Augustines and the pilgrimage churches. With the religious orders were connected the religious orders of knighthood, which combined the lives of soldiers and monks, whose architectural labors especially extended to the castles of the Order of Teutonic Knights in Prussia (Marienburg), and also to designs of hospitals.

The monasteries were so completely supplied with all the necessities of life, that a really isolated life could take place in them; all necessary trades and art industries were carried on therein; architects, sculptors, painters, masons, stonecutters, cabinet-makers and locksmiths, wrought therein, as well as workmen employed for other material needs of life. The most complete plan of a monastery, such as scarcely ever existed, is shown by the well known parchment drawing of the Benedictine monastery of S.Gall. One of the finest and most extensive Cistercian monasteries is that of Maulbronn.

14. Development of Mediaeval Architecture.

The law of development of mediaeval architecture was studied by Franz Martens with especial care, and his results were published in a series of works.

The chief points of view fixed by Mertens are the following:--

1. On the entrance of Christianity into Germany and the founding of the church, almost all buildings were of the plainest character, chiefly built of wood, also small and bad buildings. All were later rebuilt, few preceding 1000 being preserved.

2. The development of architecture produced a series of monuments in intimate relation to each other and exhibiting gradual progress; these monuments are termed by Mertens "creative buildings" and to each member of this series are joined ramifications, which indicate the local spread of results thereby obtained. The creative buildings are generally prominent monuments, the main line making strong advances, the side lines frequently continuing independently for a long time; hence in the 12th and 13th Centuries all steps in the development of mediaeval architecture occurred at the same time that men built in different places in the Romanesque, Transition, and Gothic styles, while before the middle of the 12th and after the end of the 13th Centuries, all countries at least exhibited unity in in style, even if with different coloring.

15. Extension of Mediaeval Architecture.

Different branches of mediaeval architecture extended from France to England, Belgium, Scandanavia, and Spain; Germany was most important to the countries on the eastern border, and partially influenced Scandanavia, Holland and Lombardy in a lesser degree. This affected Central and lower Italy, Sicily and Dalmatia.

The Romanesque style generally prevailed in all those countries until the middle of the 12th Century, and in its highest works may be termed the style of the vaulted basilica with square bays. About the middle of the 12th Century, there commenced in the most distant places a transformation of the Romanesque style, which found its result in the choir of the Abbey Church of S. Denis near Paris. Abbot Suger was head of the monastery from 1121, was already busy with the facade of the church in 1140, then commenced the rebuilding of the choir and nave. The movement in architecture continued until the building of Notre Dame in Paris, begun in 1177, its facade being completed at the beginning of the 13th Century. The period just before 1140 may be called that of the French transition style, and that from 1140 to 1212 the era of the early Gothic style, especially that of the groin vaulted basilica with hexapartite groin vaults. If early Gothic had in view the perfection of the system, then the period from 1212 is that of the development of the Gothic style at its richest. The Cathedral Rheims is at its culmination. Thereafter no new element was added to the Gothick but all its parts was completed; what further follows is the extension of the style and its modification by local conditions and requirements. The period from 1212 is that of the groin vaulted basilica with rectangular groin vaults; the period after 1250 is that of the decadance, of that escape from all rules, and of application to all conceivable arrange-

ments of plan, with finally, the loosest freedom and decay.

Conditions were quite otherwise in Germanyp this likewise took part in the general advance of civilization at the time of the Crusades, but while art and culture were concentrated in Paris about the middle of the 12th Century, no central point existed in Germany. There was rather to be noticed a striving flor individual treatment of life, than a desire for harmony. The Romanesque style was so deeply rooted in all Germany and so popular, that the first vestiges of Gothic orly showed themselves after Notre Dame at Paris was practically completed. The transition style appeared first on the western choir of the Cathedral at Treves (1152-1169) and lasted in Germany until 1250. Although the perfected Gothic style earliest appeared on German soil in the Liebefrauen Church at Treves, and although the present Cathedral at Cologne was founded 1248, we find the same yeai the completion of the Church of S. Kunibert, decidedly in the transition style, the Romanesque being further employed after 1284 and 1285 in various places. We see from this that Germany mediaeval architecture displaced that of France, so that progress in the style on German soil occurred almost half a century later than in France.

16. Different Tendencies of German Transition Style.

The transitional style decidedly differs from that in France. It was truly in France a transitional style, so far as this means improvement of the Romanesque and the origin of the Gothic, but in Germany it was merely intermediate between Romanesque and Gothic. The three tendencies of the transition style strongly differed from each other as follows:-

1. That which begins on the western choir of the Cathedral at Treves and chiefly extens through the Rhine provinces. By using special building materials, such as tufa for walls and vaults, trachyte for structural parts, and black slate for small columns, it gave the Rhenish buildings a peculiar decorative character, which wae its object, more than improving the system of building with reference to the construction.

2. A second, entirely differing from the previously mentioned transition style, originated in Germany from the endeavor to master defects of Romanesque by other methods than those of French Gothic. This tendency especially proceded from the Cistercian monasteries, was a structural style, and may be considered as a reaction against the invading Gothic. The finest example is the Cistercian Church at Heisterbach, 1203 to 1233, in its way unique in Germany and elsewhere. The plan is indeed somewhat like that of S. ETIENNE at Caen, also having an aisle around the choir with seven radiating chapels, but the vaulting of the rectangular bays of the plan was done in a peculiar way: instead of the pointed groin vaults of the Gothic, the German-Romanesque combination of groin and classical vaults was employed throughout.

The Cistercians exerted a stronger influence on Architecture in Germany than in France, and the few remaining examples of their endeavors to perfect a structural architectural system allow the conception of a style-tendency, parallel though opposed to French-Gothic, which might perhaps have arisen had not this purely German transition style been interupted and restricted in its development. The ground ideas of this tendency and of French Gothic were the same, but the methods of execution were different; it was applied to the construction of the rectangular groin vault, avoiding pointed architecture. We shall give particular attention to this problem later.

3. A third tendency of the transition style found in Germany endeavored to adopt and utilize the progress made in France; it prepared the ground for the later Gothic style, and accustomed Germany to the new forms, so as to prepare for the abrupt entrance of a perfected Gothic style. But the earliest Gothic monument, the Liebfrauen Church at Treves, founded 1227, did not give the strong impulse permitting the introduction of the Gothic style throughout all Germany, but this was due to the founding of the Cathedral of Cologne in 1248, soon followed by the extension of the Cathedral at Strasburg in the Gothic style.

17. Nature of Late Gothic.

Franz Mertens first clearly made known the nature of late Gothic. His ideas may be briefly stated:- 1. It presupposes the completely developed Gothic style. 2. It is based on the development of certain germs, already existing during the best period of Gothic, and on their extension, aided by a later common decadence in taste. 3. Aside from local influences, this develops both toward simplification, and toward transformation of perfected structural forms.

Simplification commenced in France with S.Urbain at Troyes, in Germany with the Begging Friars:- S. Urbain at Troyes was founded 1261 to 1264. The first example in Germany was the Minorites' Church at Cologne, 1270 to 1280; it was a weak style, due to masters of less talent and power.

Transformation of architectural forms occurred un a purely decorative sense, by exaggerating and sharpening them, or by their effeminacy and jewel-like connections. Marks of this tendency were already apparent in French Gothic, according to Franz Martens; the cloister of the Minorites' Church at Cologne was the first example of this tendency (1293). Although the Late Gothic bore within itself the germ of decay, we may not deny that it created much that was beautiful and original, made much progress in construction, and produced numerous graceful and picturesque combinations.

It is unjust to regard Late Gothic as merely a decadance, for we may discover in it not a few germs capable of development, which may now be utilized. That mediaeval masters even employed the severe forms of the best Gothic in the same design with Late Gothic forms, to produce by contrast more vivacity in the closely

restricted system, we have evidence in a drawing for a massive tower, found at Regensburg, whose designer placed very severe and very fanciful forms of tracery beside each other for contrast, and also in the original drawings for the Cologne Cathedral.

18. Schools of Southern France.

We have given a view of mediaeval architecture in the general lines of its cour of developmentp if we wish to carry this further, we have to mention in France th types of Provence, Languedoc, Aquitaine, Auvergne, Burgundy, Normandy, also of Is de-France (royal domain), and to speak of the provincial German styles of Lower, Middle and Upper Rhine, Saxony, Frnconia, Swabia, Bavaria, Austria, and the north German lowlands. We must also remember Lombardy and western Italy.

1. Provence, the true Roman province, was a climate like Italy and is rich in Roman monuments. Buildings in Romanesque are small, heavy and gloomy structures, with one or three aisles, almost exclusively covered by round or pointed tunnel vaults strengthened by transverse arches; plane stone roofs could be used there, r ing on the tunnel vaults. In designs with three aisles, the thrust of the tunnel vault of the middle aisle was transmitted through the half-tunnel vault of the side aisles to the external walls. Mettens says that the small monuments are due to subdivision of the provinces into many dioceses; the character of the architecture in its details is entirely determined by nearness to Roman monuments; it even approximates more closely to the Antique than do Italian buildings of this period. The most important buildings are the Churches of Notre-Dame-des-Doms at Avignon, of S. Gilles, and the Cathedral of S. Trophime at Arles. Romanesque Switzerland follows Provence in its architecture.

2. The School of Languedoc, the province belonging to the Counts of Toulose, lying between Provence, Aquitaine, and the Pyrenees, exhibits a character similar to that of Provence, but the buildings are much more imposing in design. The decoration likewise shows a predominating Roman character. The chief monuments are the Abbey-Church at Conques (1035-1060), S. Sernin at Toulose (1096), a noble three-aisled plan with choir-aisle and radiating chapels, three-aisled transepts, with tunnel vaults over the middle aisle and strengthening transverse arches.

3. In contrast with the two just mentioned, Auvergne is an inland province without fine Roman buildings. The chief building is the Church of Notre-Dame-du-Port at Clermont-Ferrand, (end of the 11th or beginning of the 12th Century), allied in plan to the churches of Languedoc, and also covered by tunnel vaults, but strengthening transverse arches are omitted; its stone roofs also rest directly upon the vaults. The church has three aisles; the side aisles are in two stories with galleries, lower story covered by groin, upper by tunnel vaults. Characteristic of Auvergne and due to the chiefly volcanic mountains, which supply building materials of different colors, are the mosaic patterns of the masonry imitated

from opus reticulatum in extensive use even in the Early Christian period. The churches of Auvergne are otherwise inferior to those of the former provinces in richness of sculptured ornamentation. The Church of Notre Dame du Port serves as a odel for a series of other similar designs, first for the Church at Issoire.

19. Divisions of Aquitania.

Aquitania is divided into three provincial types, of Perigord, Poitou, and Anjou. Perigord comprises the dioceses of Periguex, Angouleme, and Saintes, with Periguex as the central point. The churches of this country are all domical structures. Poitou, with Poitiers as capital, is characterized by three-aisled churches with aisles of equal height, (hall churches), or with a clearstory over center aisle, as well as by churches of a single aisle. Basilicas are almost entirely wanting. Anjou, with the cities of Angers, Mans and Tours, is by its situation chefly allied to the North. From the middle of the 12th Century all these countries belonged to the Plantagenets.

Perigord is also noted for its important church at Periguex, built on the Greek cross plan, an imitation of the Church of S. Mark at Venice. The characteristics of the church at Periguemx are its being covered by domes, separated by cornices from the pendentives. At the restoration, these pendentives were entirely built of horizontal courses, thus by corbelled, their builder imitating a form, not clearly understood by him. Viollet-le-Duc has very fully explained this imperfect construction, after all merely an inconvenient refinement; the quite primitive construction of the vaults and the peculiar form of the bell-tower of the church make it appear scarcely doubtful, that the date of 1047 for the dedication of the church is correct for the existing building and its domical vaults. The domes are pointed and the pointed arch is employed here for structural reasons as in the south-west provinces (V-L-Duc, I - 171; IV - 350; VII - 110).

The system of domical forms at Perigueux applies to a series of other churches at Souillac, Cahors, Angouleme, Tremolac, S. Avit at Solignac, S. Emilion, S. Hilair at Poitiers, Fontevrault, Boschaud, etc. But all these churches have the Latin cross plan or are without transepts. The transverse aisle and choir are usually covered by tunnel vaults, and apses generally have a choir aisle and radiating chapels. Such are the churches in the dioceses of Angouleme and of Saintes.

While the church at Perigueux has in its masses a decidedly foreign, Byzantine appearance, it adheres to Roman forms in details; the character of these buildings is entirely Romanesque, and Roman details are almost entirely replaced by rich ornamentation with partly Norman forms, partly those recalling Celtic interlacing bands, mixed with animal forms and grotesques.

With these buildings should be mentioned the Abbey Church at Fontevrault, whose eastern part was built after the middle of the 12th Century and contains a new element; the intersection of the nave and transverse aisle being covered by a pend-

entive dome without a horizontal cornice, so that the system of Perigueux has give place to a better one, more easily constructed. At about the same time, true Gothic already existed in its chief elements in S. Denis.

Northern Aquitania, the diocese of Poitou, very distinctly differs from Perigord; the most imperfect and oldest examples of this provincial type are the churches of Notre Dame la Grande and of S. Radegende at Poitiers. One fragment of Byzantine architecture, the pendentive dome, continues in use in these parts, but eight purely ornamental ribs subdivide the vault, a form derived from the northern provinces of France and without any structural meaning: the vaults are entirely constructed with wedge-shaped voussoirs radiating from a center. Even in the beginning of the 12th Century, the single aisled Cathedral at Angers, was built (1145-1165), in plan recalling the similar Cathedral at Angouleme, extended by adding a transverse aisle and choir with domical vaults divided by eight ribs. The Cathedral at Poitiers, a three-aisled building with slightly raised central aisle, is similarly covered by domes with eight ribs. We find a second type of plan of church in Poitou in the Church of S. Savin at Poitiers; three-aisled in contrast with the preceding churches, but of entirely different type. The raised center aisle is covered by a tunnel vault, with groin vaults over side aisles. Both churches, the Cathedral and S. Savin at Poitiers, have in common with the foregoing churches the center aisle without windows, the entire interior therefore being very dark; but differ in that the roofs are no longer of stone but are of wood in provinces more exposed to rain, then covered by tiles. Instead of square piers with engaged columns, the vaults in S. Savin rest on round piers.

In like manner and with domes having eight ribs, the churches of the province of Anjou at Angers, LeMaus and Tours are vaulted. The churches of Poitou, especially that of Notre Dame la Grande at Poitiers, are characterized by their richly decorated facades (Lubke, 454).

All these churches have a heavy and gloomy character, unavoidable with small windows and defective lighting of the centre aisle; their second peculiarity is the almost exclusive use of stone roofs, necessarily replaced in the rainy northern provinces of France by wooden roofs, covered with various materials, tiles, slates, or metal sheets. Various ways were used to obviate the gloom of churches with central aisle covered by tunnel vaults and without direct lighting.

Climatic conditions and the geology of southern France, together with the fixed and conservative character of its people, chiefly determined the evolution of its architecture. Throughout the remainder of France an important influence of Germanic peoples made itself felt therein. With active introduction of Germanic elements, an endeavor to perfect architecture originated from their mixture with other races of different nature but with great talents, and happy combinations of their varied peculiarities result.

20. Burgundy and Churches.

Burgundy is bounded on the south by Auvergne,on the west by Aquitania and Isle-de-France,on the east by Germany; in eastern France it plays an important part in the development of mediaeval architecture. It belongs to the districts influenced by Roman monuments, in which it is rich, especially at Autun. It not only borrows from Roman buildings their decoration, like Provence, but also their structural elements. Sculpture is used, not merely to cover surfaces, but is concentrated on points made prominent by construction.

Church architecture is especially characterized by a decided acceptance of the basilica with clearstory windows, and by the grand design of the building. The internal piers are frequently treated like Roman fluted pilasters, and the ribs are subdivided into rounds and richly decorated mouldings.

The oldest monument in Burgundy was the Church of S. Benigne at Dijon, built by an Italian abbot William, which has entirely disappeared. It was erected on the Latin cross plan (1000), and to it was added a three-story circular building with two aisles around the central space enclosed by eight columns, which rose above the three stories and probably ended in a conical roof of masonry. The rotunda was an imitation of the Church of the Holy Sepulchre at Jerusalem, and (V-l-Duc, VIII-200) contained a large crypt, more than one hundred marble columns for its court being brought from Italy. Massive staircase towers connected the three stories.

Another building by the same abbot William was the Church of S. Philibert at Tournus, (after 1007), a three-aisled vaulted basilica with a vestibule, as in Burgundy, in every way differing in design from the preceding churches, since the semicircular transverse arches of the central aisle support tunnel vaults at right angles with the longitudinal axsis of the church. The supports of the vaults are massive round piers; the side aisles are covered by groin vaults. This awkward and heavy system of vaulting enabled the architect to place windows in the upper walls of the central aisle. Adjoining the nave is a transverse aisle with choir, circular aisle and radiating chapels.

The use of transverse tunnel vaults occurs independently of this church over side aisles of churches in different places. Lighting the central aisle resulted from placing the tunnel vault over the entire middle aisle so high above the roofs of side aisles as to permit windows in clearstory walls above these roofs. This occurred in the Abbey Church at Paray-le-Monial, also in the Cathedral at Autun. (commenced 1132).

From the impossibility of covering side aisles by abutting half tunnel vaults, it resulted that the side thrust of the tunnel vaults of the middle aisle must be resisted by buttresses, with the disadvantage that the total height of the building must be materially increased, and still the end was but partially attained. In

spite of buttresses, the vaults of the central aisle threatened to overturn the clearstory walls, and although such churches were long built, their defects were evidently plainly felt; on the great Abbey Church at Cluny, built on the same system (1089-1130), on the Church at Beaune, and on the Cathedral at Autun, buttresses were necessarily added in the 12th and 13th Centuries to remedy these evils.

This system of construction was abandoned in building the fine Abbey Church at Vezelay, for instead of tunnel vaults over each bay of the middle aisle, groin vaults without ribs were introduced (after 1120).

The most important and grandest building in Burgundy was the Abbey Church at Cluny, unfortunately destroyed; it afforded the most perfect type of the Burgundian churches. This church had five aisles, two transverse aisles, a long 3-aisled vestibule, a choir with circular aisle and radiating chapels, and nine towers; it was decorated with magnificent sculptures and costly building materials. Ablot Hugo commenced the Church in 1089, and had columns of Pentilican marble and Cipolline thirty feet long brought by sea.

The Cathedral at Autun borrowed its details from Roman Gates there (Porte d'Arroux); likewise for the Cathedral at Langres and for other churches in this country, rich in Roman buildings; fluted pilasters, Corinthian-like capitals, and mouldings resembling Roman, are characteristic of these buildings. Members and ornamentation are bold and tasteful throughout Burgundy, and so far as not influenced by antique forms, harmonize with the treatment of details of the Romanesque style in the adjoining provinces. With the introduction of the groin vault over the bays of the middle aisle, the old system of vaulting was dropped, preparing for farther steps in the evolution of the vaulted basilica.

21. Normandy and Churches.

From their native country of Normandy, the Normans conquered England in 1066 under their strong and able Duke William. The Norman nobles thereby won great estates in the conquered country, and their religious feelings led them to found convents, churches, and monasteries, which they, fond of architecture and magnificence, built permanently and intelligently, decorating them as far as possible.

The plan of the Norman church is always the Latin cross; side aisles extend beyond transepts, but do not, as in almost all provinces previously mentioned, form a circular aisle around the choir, or end in small apses, almost always ending in square form. The central aisle terminates between these squares in a semicircular apse. Side aisles generally have galleries above them, or a triforium takes their place, a passage in the clearstory wall with arcades next the central aisle, outside it being the roof of the side aisle. Except in the Cathedral at Autun, triforiums do not occur in the parts of France already mentioned.

Vaults were at a very early date almost entirely groin vaults, the galleries being sometimes covered by half tunnel vaults, as in the southern provinces. The mid-

dle aisle was usually covered by hexapartite vaults, which were not so early in use in the rest of France or Germany. The early and common use of groin vaults led to the use of the pier with semicircular projections for support. Columns do not occur in Normandy. The exterior of the Norman church is always characterized by two square, slender wrstern towers with tall spires, and by a massive tower over the intersection. The subdivision of the external wall is quite different from that in South France and Germany; pilasters are in common use in Germany, connected by a round-arch frieze, while in southern France projections from walls are mostly in the the form of semicircular piers, whose capitals are connected with the entablature and are supported by corbels; Norman buildings have moderately projecting buttresses ending beneath the main cornice, which usually rests on corbels. The facade with two towers is divided in several stories and is decorated by a great portal.

The entire ornamentation in Normandy differs essentially from that of the remainder of France. Excepting the attic base and some forms resembling the Corinthian capital, all Roman reminiscences are avoided; it likewise excludes all plant forms and is satisfied with geometrical shapes of the most diverse kinds, very strongly recalling wooden architecture and its simple carved forms; we meet these forms again on the Romanesque buildings of Germany. With them are usually found interlaced animals with very varied applications. The decoration by these simple means is concentrated on places requiring ornament, gives the buildings a substantial though brilliant appearance, and they are strong and sturdy, though rich in effect. The Abbey Churches of S. Etienne and S. Trinite at Caen were both founded 1068, and with the Church of S. Nicolas, are the most important examples of this Norman architecture.

22. Churches in Isle-de-France.

Isle-de-France (royal domain) is not especially prominent in Romanesque architecture, but is characterized by a combination of all elements of the types of architecture mentioned. It contains a new structural element, not occurring elsewhere in France or Germany, of the greatest importance to the evolution of the Gothic style, the strongly projecting buttress, shown by Franz Mertens (1843) to occur in several Roman buildings in Paris, and transferred from them to the Church of S. Germain-des-Pres (997-1031). The flying buttress was introduced as a structural element to receive the thrust of the vaults of the central aisle and transmit it to the walls of the side aisles; according to Mertens, it may already be recognized on the Church of S. Benoit-sur-Loire (1070-1080).

Mertens says for this province (1864) that Romanesque architecture is here already so nearly Gothic and Gothic architecture contains so much Romanesque, that it all combines to form a single style.

23. Abbey Church at S. Denis.

After various preliminary steps already stated, the Gothic style appears fully

expressed in principle in the Church of S. Denis at Paris. To make the importance of this building and the creative activity of Abbot Suger evident, this building will be treated at length.

The Abbey of S. Denis was a rich foundation and the burial place of the French kings. Suger was chosen Abbot in 1121; an existing older church with a crypt had become too small, and Abbot Suger commenced a new structure on the old foundations, leaving us a detailed account of its erection. He strove to attain the highest point then possible in architecture. Schaase says (V, 33) of Suger: "He took part himself in every part of the construction and decoration of the church, went into the forest where trees were felled, and endeavored to use his artistic school studies. He collected as many foreign artists from Lothringia and other countries as possible and emulated all great works known to him, or of which he had heard. Desiring to have such columns as he had seen in the Palace of Diocletian at Rome; he estimated the cost of having them brought from Italy by aid of the Saracens, but was so fortunate as to find a good stone in a neighboring valley. He gladly exhibited art works already completed to those returned from famous countries and acquainted with the treasures of the Church of S. Sophia, and felt flattered if they declared his possessions to excel."

He began with the west facade, dedicated in 1140; this, like Norman churches, has two towers, contains a porch between the two towers and a gallery above it, lighted by three windows, one round-arched between two pointed-arched; the porch is adorned by three massive portals with forms of arches alternating like windows. Above the windows of the gallery is a wheel window, an idea appearing for the first time, according to Mertens, in the Church of S. Etienne at Beauvais.

The three principal doors of the facade were covered by enamelled plates of copper decorated by gold ornaments (V-1-D, I, 39). The deep jambs of the portals were richly subdivided and decorated by relief ornament. The entire facade with massive and slightly diminished towers, later completed by stone spires with four angle pinnacles, recalls that of the Church of S. Etienne at Caen. The choir was nobly planned and finely executed; Abbot Suger commenced this after the completion of the west facade, retaining the ancient crypt (V-1-D, III, 233). He adopted the motive of the southern French choir and its aisle with radiating chapels, which for the first time formed here a complete series of seven chapels; the main apse was surrounded by eight columns. This choir became the model for most later Gothic cathedrals. Groin vaults with circular diagonal ribs and pointed transverse ribs had already been first used in the vestibule of the Abbey Church of Vezelay; Abbot Suger used this motive and brought it to its fullest development in his choir.

The vaults at Vezelay were so built that, as in all ribbed vaults preceding S. Denis, the diagonal ribs were not structural members indispensable to the stability of the vault, but merely stone centering arches for aiding the construction of the

vault (V-)-L, IX, 501). In the choir of S. Denis, Suger with clear knowledge assigned to these vaults their structural uses in architecture; the vaults chiefly owe to the ribs their stability, and would lose their permancy without them; they owe to the combined use of the round and pointed arches their suitability for being built on any form of ground plan without especially complex methods. The entire choir of S. Denis was covered by three vaults, and the pointed arch already used on the facade was also consistently employed on the windows of the choir for both practical and esthetic reasons, for its harmony with the longitudinal arches of the vaults. The nave was commenced by Abbot Suger after the completion of the choir, retaining the old walls; like the upper part of the choir, it was later entirely rebuilt and changed under Louis IX into the form in which it now appears.

While the Church of S. Denis the entire construction and even the mouldings are already Gothic, the forms of the ornaments are decidedly Romanesque, and exhibit scarcely a tendency towards the northern flora, from which the riper Gothic derived its forms. Compared with earlier designs of churches, the entire building is light in masses and slender in proportions.

If we summarize the peculiarities of the French schools of architecture, we shall obtain the following statement:

Normandy.	Burgundy.
Groin vaulted basilica in Latin cross form with simple choir; facade with two towers; tower over intersection; rich ornament derived principally from geometrical forms.	Basilican designs, mostly with tunnel vaults and in Latin cross form, with richly developed choir and radiating chapels, porches and imposing towers, ornamented like the Antique.
Royal Domain.	
A combination of the other types. Architectural ornaments not very prominent; tendency toward Gothic; strongly projecting buttresses native here.	
Aquitania.	Southwest Types.
Generally with a single aisle, domed; sometimes in three aisles with tunnel vaults; plans not basilican, but with choir aisle and radiating chapels. Tower over intersection. Ornaments rich and fanciful, strongly influenced by Celtic elements.	Provence, Languedoc, Auvergne. Three-aisled non-basilican designs with tunnel vaults, usually with galleries and very high middle aisles; stone roofs; choir aisle with radiating chapels, or choir with chapels on east side. Ornament strongly Antique; mosaic decoration of walls in Auvergne.

24. Romanesque style in Germany.

Before treating the further development of Gothic, we have to consider the Romanesque style in Germany until the middle of the 12th Century. Germany was politically united in the middle ages and comprised many closely related races, so that in architecture there prevails a quite uniform general character. This very materially

differs from the French, since many elements employed in France are entirely foreign to it; aisles with domes or tunnel vaults seldom occur, and excepting a few cases, radiating chapels are not used in German Romanesque. Stone roofs, buttresses or semicircular projections are found only in quite isolated examples. Germany decidedly differs from France during the Romanesque style in :---1. The extensively used plan of church with duplex choirs; 2. The triapsal design; 3. The alternation of supports in the interior, sometimes of piers with columns, sometimes of heavy and light piers; 4. The columnar basilica; 5. The invariable basilican arrangement of churches with three aisles, with or without vaults; 6. The constant use of grain vaults in vaulted buildings; 7. The prevailing subdivision of external walls by pilasters with arched frieze; 8. The low and open galleries, probably derived from Lombardy.

The wheel window scarcely occurred to decorate the gable in the French Romanesque, but is frequently of great importance in Germany, although only when Gothic had already been created in France, and it is therefore to be considered an element under the influence of the new French Gothic style. As the older form of design of German churches, the basilica with German columns is usually rare, though several examples occur. The chief provinces in Germany which assist in the evolution of the Romanesque style are the Rhine provinces and Saxony; the remainder of Germany is more or less dependent thereon. We will explain these in detail.

25. Rhine Provinces.

The basilica with piers almost generally prevails, at first with horizontal ceiling, afterwards vaulted. The most developed form is that on the plan of S. Gall, and later on that of the Abbey at Fulda, a church with duplex choirs and transepts, next the triapsal design, derived from the imperial Palace at Treves, as in the Church S. Maria-im-Capitol at Cologne.

The Rhenish plan with duplex choirs required accenting the intersections of nave and transepts by towers over them; the middle part of the eastern transepts sometimes alone served as the church, the outer transepts being divided in several stories and used for purposes accessory to divine service. Such transepts required staircase towers to connect the stories, and others were necessary to make the upper part of the western choir accessible, thus producing the imposing design of a cathedral with six towers, first built at Fulda, St. Gall, and the old Cathedral at Cologne, and caused by the requirements. Until a tolerably late period, this design exercised its influence in the border provinces of France as well as on the lower Rhine and in lower Saxony. Imitations appear in eastern France in the Cathedrals at Besancon and Verdun (V-l-D, I, 209). In northern Germany are good examples of such buildings in the Churches of S. Godehard and of S. Michael at Hildesheim, the first completed 1133, the second built 1164-1184 and consecrated the last year.

The Rhine provinces were controlled by important cities and bishoprics (Mentz,

Spires, Worms, Cologne, Strasburg), and their buildings are therefore grand and richly ornamented; their great masses and picturesque groupings combine with strongly decorative expedients, such as open external galleries; the subdivision and decoration is severe and dignified, rich and animated. The cathedrals at Spires, Worms, and Mentz exhibit varied tendencies in taste: the first is earnest, massive and plain; the Cathedral at Worms is luxuriant and fanciful, recalling French, especially Norman buildings; the Cathedral at Mentz harmonizes with the grandeur and simplicity of the Cathedral at Spires, and is partly influenced by the animated architecture of the lower Rhine. All three cathedrals are dry and bold in details, in accordance with the building material---sandstone of strong colors.

As previously stated, the buildings on the lower Rhine, and at Cologne, owe their distinctive character to the peculiar volcanic building materials of the Eifel mountains, as well as to the product of the Rhenish slate mountains. The hard trachyte from the Drachenfels is especially used for structural parts and demands simple treatment; the easily wrought tufa from Lake Laach makes the richest ornamentation possible. The easily split black slate is better polished than cut and is therefor used for columns; slate rubble gives a gloomy and unfinished appearance to the buildings.

From these materials, buildings on the lower Rhine obtain rich animation, accuracy in execution, and piquant effect by the use of complex structural motives, easily executed in tufa, and more refined treatment of details, than is found on the middle and upper Rhine, and also a more effective harmony of color with light tufa as building material, with which the small black slate columns strikingly contrast. This style of architecture extends into all side valleys on the lower Rhine, and although at Treves the Romanesque style mixes with French forms, yet the architecture there belongs essentially with that on the lower Rhine.

The buildings on the upper Rhine, around Strasburg, Freiburg, and Basle, practically belong with those of the middle Rhine; in accord with the bright colored sandstone, their decoration is heavy and earnest in treatment; from upper Alsace, as at Rosheim, a fanciful and bizarre tendency radiates through Basle to Zurich and other places in Switzerland, but from lower Alsace, especially at Strasburg, a nobler style extends to Freiburg and points dependent thereon.

26. Saxony.

Saxony attained prominence under the Ottos, and men early became accustomed to wooden buildings, which furnished a motive for the round pillars of churches. To economize costly stone columns, in the construction of stone churches, piers were used at the principal points of support. This produced the motive of alternating piers and columns prevailing in the basilicas of the Saxon provinces. The plan is generally that of the Latin cross with a simple choir apse, usually with side apses at ends of the side aisles. This plan easily led to western facades with

two towers including between them a vestibule and gallery above, as for the church at Gernrode consecrated in 964, or as in Westphalia, where the middle part of the western facade was developed into a massive tower, while the sides were reduced to low staircase towers, as on the Cathedral at Paderborn, dedicated 1143.

The churches in upper and lower Saxony are usually less distinguished by dimensions and by importance of architectural motives, when compared with those of the Rhine provinces and other parts of Germany, than by variety in design and development of motive in detail. Originality and refined feeling for treatment of details are expressed, which might almost be termed the classicism of the Romanesque style. While the Rhenish provinces employ the vault-pier, Saxony develops the rectangular wall-pier with decorated angles, which is suited to the basilica with horizontal ceiling.

27. Remainder of Germany and Europe.

In Franconia, with the important dioceses of Wurzburg and Bamberg, architecture is for commercial reasons less closely connected with the Saxon provinces than with the Rhenish. Wurzburg, Bamberg, and Hesse with its ancient Abbey at Fulda, were essentially influenced by Mentz and Worms; while the less important monuments in Hesse at Fulda, Herrfeld, Ilbenstadt, and Gelnhausen, likewise have middle Rhenish architecture in accordance with the building material of colored sandstone; the dioceses of Wurzburg and Bamberg pursued another development of the style, favored by a soft yellow sandstone, the detail is finer and richer, with a nobler treatment of the whole. Romanesque architecture in Suabia essentially depends on the Benedictine monastery of Hirsau, built 1082-1091.

Bavaria is active in the development of architecture at Regensburg, already important in the Middle Ages; like Cologne and Treves, this was richer than other German cities in Roman monuments, which influenced its architecture; as an important transfer point between Germany and Italy, it later received many influences from the south; many peculiarities were brought to it by the Scotch monks at the end of the 11th Century.

Bavaria succeeded earlier in an original development of architecture than did the Rhine provinces, dependent upon Franconia and Suabia, and this distinctive character is retained until later times. It is distinguished in Regensburg and Freising by richly ornamented sculpture in Romanesque, hardly found elsewhere in Germany, occurring on the Scotch monastery after 1278, about 30 years later than the founding of the Cathedral of Cologne, perhaps imitated from the carved wooden style of the Scotch, who had already built wooden churches in Bavaria during the 7th Century.

Austria, in its important cities of Salzburg and Vienna, was the channel of commerce between western and eastern Europe; its architecture is not essentially different from that of other German countries.

The north German lowlands on the North and Baltic seas were hardly won from the

Slavs during the Crusades and take little part in architecture during this period. In both Romanesque and Gothic architecture, they differ from the rest of Germany by brick construction and by the use of granite boulders as building materials, scattered everywhere.

Other countries of Europe which took part in the development of the Romanesque style may be briefly mentioned. Italy has already been considered; we have only to add that lower Italy and Sicily mixed Norman and Moorish forms in their architecture. Spain chiefly imitated southern France; England was like Normandy; Denmark, Sweden and Norway received their architecture from England and Germany; Belgium and Holland took theirs from northern France and from Germany.

28. Early Gothic in France.

To extend our sketch of the evolution of Romanesque architecture further would not be proper, for a detailed history of Mediaeval Architecture is not intended, but merely its relations, so far as necessary to understand the mediaeval styles. We therefor now give the course of the Gothic in outline and return to S. Denis. This building was soon followed by an entire series of the most important cathedrals in France. The uplifting produced about the middle of the 12th Century in France as well as in Germany manifested itself in a generally prevailing liberality, high and low taking part both in offerings of money and of labor for the greatest architectural works. An equalled emulation affected all believers, as already evident in the erection of S. Denis, so that nobles and people with their own hands helped to build the massive stone piers, and this was repeated in the grandest way at the building of the Cathedral at Chartres, founded 1145, where "this assistance was thoroughly organized", by which "obstacles were overcome which would have appalled hired workmen." Abbots and bishops then boasted of this zeal of the laity.

The Cathedral at Chartres, whose west facade and the bases of the towers alone belong to this period, exhibits a further step in the development of the new style; especially in the pointed arch consistently employed thereon; the very broad middle aisle is externally lighted by three windows and by a colossal wheel window having the entire width of the facade, terminated at top by a horizontal arcade with figures in niches. The three portals of the facade are combined in a group, while those of S. Denis were separated by the buttresses of the tower. The further development of the style does not then proceed regularly, that each separate building might represent the unity of the style, but only a portion of each new structure adhered to the course of development of the style, while the enlargement and completion of these buildings occurred later.

The treatment of the facades of the cathedrals at Sens and Noyon was followed in the magnificent facade of Notre Dame at Paris, of dignified earnestness and great severity, with energetic and clear treatment of the style. The two stories of the facade, whose portals were separated like those of S. Denis, are divided by a great

arcade decorated by statues, and the upper story with the great rose window at its center is terminated by a similar arcade. The towers have windows in pairs and rise arcade with a more slender treatment than those of S. Denis.

The system of the facade of Notre Dame at Paris, at the highest point in development and with the richest ornament of the perfected style, is found in the Cathedral at Rheims; all the plain masses of the angle buttresses of the towers are here replaced by open canopied niches containing statues; the portals are again joined in a group, which projects before the facade; the windows have gables over them and are filled with tracery, which was wanting in Notre Dame at Paris. This facade was built after 1241, eight years before the founding of the Cathedral at Cologne, and is the most beautiful facade produced by French Gothic, even being the most magnificent facade which exists.

After S. Denis, the entire system of construction of the nave with its imposing choir is developed in a series of cathedrals; most important was the perfection of the groin-vault, indeed the change from the hexapartite to the rectangular groin-vault. Then the development of the pier in the interior, and of the flying buttress and buttress on the exterior, with a general reduction of structural masses by the use of great windows with tracery, the common use of the pointed arch, subdivision of the interior and exterior, the forms of towers, and lastly, the details and ornamentation. The Cathedrals at Paris, Laon, Sens, and Noyon the Churches of S. Germer near Beauvais, the Abbey of S. Remy at Rheims, the Church of Notre Dame at Chalons-sur-Marne, the choir of S. Germain-des-Pres at Paris, all take part in this development of the style.

Attached to nearly all of these churches and grouped in their vicinity are a number of smaller imitative structures, the first series of great cathedrals in which the style was developed being followed by another series extending it. To this belong the Cathedral at Le Mans, the Abbey Church of S. Ived in Braine, the Cathedral at Beauvais, and others.

In the Cathedrals at Amiens)1220 - 1288) and at Rheims, (1241 to 1300) these creative monuments attain their purpose and their highest point. The relative heights increase, the Latin cross plainly appears in the middle and transverse aisles, raised high above the side aisles, and the choirs extend in length; two towers are usually added to the transept facades like the western facade, and a high tower is even placed over the intersection; a like church with seven towers was planned in the Cathedral at Laon and executed in reduced proportions in the Cathedral at Limburg-o-Lahn. The choir aisle with its series of chapels remains in France the general type of the terminations of the plans of cathedrals. Round piers were preferred in the older cathedrals, with groups of shafts for dividing the wall and springing from their capitals, but these were transformed into clustered piers with four round shafts.

29. Best Period of Gothic.

The best period of Gothic style begins with St. Louis, who commenced in 1231 to rebuild the nave of S. Denis, and was a noble, art-loving prince, whose era is compared by French archaeologists with that of Pericles. His finest creations are the famous S. Chapelle in Paris, a pearl of French Gothic, the beautiful Church of S. Nicaise, and the facade of the Cathedral at Rheims. Though the creation of the new style only extended around Paris as a center, the second extension of the perfected style reached all parts of France, and was variously colored by local conditions. It was especially the Cistercians that took the most active part in this extension.

30. Extension of Gothic outside France.

Outside France, England first adopted the new style. The Cathedral of Canterbury was burned in 1174. William of Sens in France was called to rebuild it, and brought over the new style. Thence the Gothic extended generally over all England, always using peculiarly different forms. Germany, Italy, and Spain received the Gothic at about the same time: Germany in the Liebfrauen Church at Treves (begun 1227), Italy (about 1228) in the Church of S. Francesco at Assizi, built by a German Master, and Spain in the Cathedral of Toledo (built 1227). Gothic was long prepared for in Germany; the first purely Gothic building was kept in consistent German style, while the Cistercian Abbey Church at Marienstadt in Nassau, begun in the same year 1227, is one of the few German monuments with a purely French character. Even in the earlier Italian building at Assizi, the local style of Gothic is very distinctly expressed. Spain first imitated the cathedral style of northern France, and the style only later became strongly mixed with local Moorish forms. Belgium and Holland likewise received (about 1230) the developed Gothic style from France.

31. Extension of Gothic in Germany.

The Gothic style in Germany proceeded from Treves along a few main lines; yet in some places is found a direct importation of the style from France, or at least a direct influence; it may be that from the moment in which Gothic became the fashion, architects studied the style at its source when possible.

The Liebfrauen Church at Treves has the quite peculiar plan of the Latin cross (Fig. 10) with reentrant angles filled by chapels, its four arms ending in apses; its plan therefor resembles that of a central building, while the cross form is very decidedly expressed in its upper part. The plan did not result, as Mertens stated, from doubling the plan of the choir of S. Ived at Braine near Soissons, but from limitations of the site. All forms of the church are decidedly Gothic, and the ornamental details are mostly based on native plant forms.

The noblest endeavor of German Gothic may be found shortly afterwards (in 1233) in the Church of S. Elisabeth at Marburg. It also exhibits peculiarities: in plan (Fig. 11), because triapsal; in section, because a hall church; even more than the Liebfrauen Church at Treves, to which it shows decided similarity, is the Church of S. Elisabeth entirely German in its forms. All details and ornaments, as well as scul-

tural decorations, are most carefully finished.

At Marburg and the Cistercian Abbey at Haina was developed a truly Hessian school of Gothic architecture, independent of the Rhenish school at Cologne. The Marburg Gothic also passed a few points in northern Germany, like the Church at Lippstadt in Westphalia, the Cathedral at Paderborn, and the Church of S. Nicholai at Obermarsburg, the Church at Nienburg-a-S', and the Cathedral at Namburg. The highest development of Gothic in Saxony occurred in the Cistercian Abbey of Schulpforta, the Cathedrals at Magdeburg, Halberstadt, and Meissen. But there an influence of the Hessian school is less apparent than direct importation from France. A second was the erection of the Cathedral at Cologne, commenced after the fire in 1248, perhaps the most important of all German architectural creations directly dependent upon France.

The plan (Fig. 12) is an extension of the plans of the Cathedrals at Amiens and at Beauvais, 5-aisled with 3-aisled transepts, choir aisle, and seven choir chapels. Only after the completion of the choir (1318) was the construction of the nave and of the great western towers commenced. The architecture is in every respect the supreme endeavor of German Gothic, and its forms are as refined as its masses are imposing.

This important monument, whose influence extended on all sides, formed a second type of Gothic architecture, developed in Cologne itself and its vicinity, up and down the Rhine; to it especially belongs the building of the Abbey at Altenburg near Cologne, the Church of S. Victor at Xanten, the plan of whose choir is allied to that of the Liebfrauen Church at Treves, the Church at Ahrweiler, the Cathedral at Utrecht, and parts of the Cathedral at Mentz and of the Church of S. Catherine at Oppenheim.

The splendid cathedral buildings at Strasburg and Freiburg are connected with the third importation of the Gothic style into Germany; the chief parts of both buildings were completed in the second half of the 13th Century; the Cathedral at Strasburg is particularly distinguished by its magnificent facade, that at Freiburg by its splendid tower, the first of those graceful perforated spires, characteristic of Germany, imitated in many places and almost entirely lacking in France. The Cathedral at Strasburg retains the magnificent style of the French cathedrals, with all its grandeur, that at Freiburg being more severe and plain in treatment.

The Gothic style first entered Suabia in the Church at Wimfen, built 1262 - 1278 by an architect from Paris. It is the perfected, flourishing Gothic style, then found nowhere else in Germany; these churches are so prominent in Germany that the chronicler mentions them as built after the French manner.

In Franconia the Gothic style is first found (in 1237) on the western choir of the Cathedral at Bamberg, which is not the perfected style of the buildings first men-

tioned, but that of the early French Gothic cathedrals at Laon and Chartres.

In southern Bavaria, Regensburg appears first with some notable buildings, the Church of S. Ulrich, (second quarter of 13th Century), a peculiar rectangular structure in early French Gothic, with galleries extending all around it, apparently with reminiscences of the Church at Martes. Compared with other German churches, this building is entirely original in design, construction, and partly in detail. The next Gothic work in Regensburg is the Dominican Church (begun 1273), which with the Minorites Church at Cologne (dedicated 1280) first exhibits the debased Gothic style in dry and crude forms. After 1272, began in Regensburg the erection of the grandly designed Cathedral, which in plan, exterior, and use of forms is characterized by originality, like the entire architecture of Bavaria.

The perfected Gothic style first appeared in Austria in a series of monastic buildings at Heiligenkreutz, Klosterneuberg near Vienna, at Imbach, and Gratz. Gothic was transformed in the domain of northern brick construction. Here was required a change in form from the cut stone style to the plastic clay, a problem solved in the most satisfactory way in northern Germany. The Gothic style was not adapted in these provinces until the 14th Century.

32. Gothic after 14th Century.

While in the 13th Century active intercourse of German architects occurred with France, making their studies at the source of the new art, in the 14th Century with an immense number of large and small new buildings and enlargements, intercourse with France had nearly ceased, and the evolution of the style was chiefly connected with the great cathedrals and their mason's lodges, developed into schools of masters.

While earlier architecture found itself chiefly in the hands of the clergy and patronized by princes and nobles, in the 14th Century it coincided with the prosperity of the cities, then the strongest agents of civilization. Parish churches, private houses and communal buildings were then the most important problems: the first required broad and light rooms, so that hall churches were especially preferred; simple choirs sufficed for divine service, the choir aisle with chapels being usually omitted. In its place is noted variety in the treatment of the choir, found only in Germany. Only small churches usually retained the choir aisle; the flying buttresses were then omitted, giving the basilican design its distinctive character. Secular buildings required the abandonment of ecclesiastical forms and transformation of the style.

The essential point in later Gothic consists in extreme attenuation of structural masses and in changing architectural forms, so that increased results could be obtained with simplified means without injuring the general effect of richness of the architecture. An increased fluidity and flexibility of forms and of their connections is further characteristic of Late Gothic, both an effeminacy and also a hardening and dryness in treatment of forms, but combining with the simplification of means an in-

crease in richness by repetition of motives.

The most prominent buildings of this period are the facades with two towers for some German cathedrals, as at Cologne and Regensburg, also the towers of the Cathedrals at Strasburg and Freiburg, the last only completed at the beginning of the 1[illegible]th Century, and those of the Cathedral of S. Stephen at Vienna; then some choirs, as at the Cathedral of Ulm, and the Church at Kuttenberg in Bohemia; also, the Liebfrauen Church at Esslingen, the beautiful Church of S. Maria at Reutlingen, the Cathedral at Thann in Alsace, the Cathedral at Erfurt, the Cathedral of S. Martin at Landshut in Bavaria. To these are added a series of smaller churches, portions of monasteries, military and secular structures of all kinds, and some great castles, -that at Marienburg in Prussia, of Albrechtsburg near Meisson, of Carlstein in Bohemia, and of Vayda Hungad in Siebenburgen.

About 1450 was founded a league of schools of masters at the great cathedrals, or mason's lodges, especially a union of the mason's lodges at Strasburg, Cologne, Vienna, and Berne, under the presidency of the master at Strasburg Cathedral. Thus an organization of the stone mason's craft was effected, both for better work and application of art, and also for a purer life. This organization had as much beneficial to German architecture as could become injurious thereto; to it is due skill in workmanship and great aptitude for the sollution of difficult problems unknown to earlier periods; proofs of this are the late Gothic towers of the Cathedrals at Strasb[illegible] Ulm, Frankfort-am-Main, Antwerp, and large tabernacles imitating towers, graceful reredoses, rood-screens, memorial columns, fountains, etc. However important these forts of the skill of stone masons in the 15th and 16th Centuries, there results from this endeavor to excel in competition, with lack of artistic training in workmen an exaggeration of stone-mason's fancies at the cost of other branches of art, so that architecture finally came to a point, where it could proceed no further and found a welcome rescue by the invasion of the Renaissance from Italy at this time, which rapidly attained its highest point.

The same occurred in France, England, and other countries, which adopted the Gothic style and developed it in accordance with local tastes; the luxuriant Gothic united with the imported Renaissance, and from the combination of two different methods of construction sprung a series of graceful architectural works, which, in spite of their evident mixture of forms, always exhibit high feeling for art and refined taste.

33. Italian Gothic.

To introduce Gothic into Italy is a greater contradiction than the reverse, the importation of classic architecture into Germany. The masters of Italian Gothic changed the new style to suit their tastes. The Italian Gothic retained the most useful ideas, derived from the results of northern architecture in its spacious churches, developed local methods, and Renaissance architects thus learned from northern Gothic to

plan clearly and practiced the construction of vaults, especially the erection of domes of wide span. In spite of brilliantly effective decoration of facades, this architecture otherwise failed in true meaning; where simplified, it gave spacious churches a vary plain character, and when richer, it remained nearly a repitition of a few ground motives. The buildings consist of slightly subdivided masses, over which often extends a rich marble covering like tapestry; a few noble architectural motives from the north are employed, arrangedin the simplest possible manner; they produce clear subdivision and accent horizontal lines more strongly than in northen Gothic; but the subdivision is repeated, and the greater prominence of horizontals would be no gain if the vertical were as strongly expressed; but the defect in the general composition cannot be concealed by marble mosaic and decorative sculpture. The finest buildings in Italian Gothic, the Cathedrals at Florence, Orvieto, and Siena, were commenced at the end of the 13th Century and continued in the early part of the 14th, all have something decidedly dilettante in spite of their magnitude and splendor, and the Renaissance justly termed this Italian Gothic barbaric. It first succeeded in what Italian Gothic attempted.

34. Synopsis of Forms of Mediaeval Architecture.

To treat mediaeval architecture in detail, we have first to make clear that its highest problem was the construction of enclosed spaces, and its highest endeavor to cover these by vaults. Everything else depends on a knowledge of vaulted architecture in the Middle Ages. The second Section will therefore comprise vaulted architecture.

Vaults lead us to the treatment of their supports; piers, columns, walls and abutments, buttresses and flying buttresses. We accordingly have to consider in Section 3 the support of vaults; in Section 4, buttresses and flying buttresses. From the combination of vaults with their supports result Section 5, the treatment of plan, and Section 6, the internal construction, the system of cross section and arrangement of longitudinal section. All three determine Section 7, on external architecture.

SECTION II. CONSTRUCTION OF VAULTS.

35. Roman and Romanesque Vaults.

Roman vaults, the tunnel, groin, and domical, occur instead of horizontal ceilings, and were either built of voussoirs, or of pots of special shape and inserted in each other, especially suitable for the construction of domes; a third mode of construction was the concrete vault. These vaults were frequently of considerable span, but were always built with such massive abutments and with such masses of material, that they appear noble and heavy. The Romanesque style hardly knew other than Roman forms of vaults. It indeed invented the helicant rampant vault for stairways. Early Christian art frequently used the vault in rich combinations and forms of plan more varied than those of the Romans; even excelling Roman buildings in spaciousness, as in the Church of St. Paul at Rome with its horizontal ceiling and the domed Church of S. Sophia at Constantinople, but essentially retained the Roman forms of vaults.

Domes have spherical surfaces; all sections a b, c d, through the center of the plan are great circles (Fig. 13); if a dome be constructed over a square room, a pendentive dome results if the diameter of the dome equals the diagonal of the square. The crowns a', b', c', d', of the side arches (Figs. 14, 14a) lie on a horizontal circle in elevation, separating the calotte of the dome from the pendentives. On the plan of a dome may be drawn any rectilinear or curvilinear figures (Fig. 15), whose vertical projections (Fig. 15a), or lines of intersection of the spherical surface with vertical planes passing through these right lines, or with vertical cylindrical surfaces passing through curved lines, form a system of circular arcs, whose points of intersection likewise lie on a spherical surface. This system is the basis of many late Gothic star vaults. Evidently above the circle separating calotte from pendentives, there may be constructed instead, a dome having a semicircular or pointed arch as a generating curve (Fig. 16). On the Church of S. Front at Perigueux and on other churches in Perigord, such domes were alone used. (V-l-D, I, 171; IV, 353).

The simplest construction of a dome is that with horizontal rows of voussoirs, each with two radial beds and two radial end joints directed the center of the sphere (Fig. 17). The keystone is then the frustum of a cone with two concentric spherical surfaces as bases (Fig. 18). Moreover, the dome may also be divided by meridians and be constructed of vertical rows of stones becoming thinner toward the vertex of the dome (Fig. 19, left half), a favorite form of vaulting in Dutch Renaissance for niches and small domes, in spite of its complexity and of its slight practical value.

A combination of the two kinds of vaults occurs in use as coffered vaults in Roman architecture, as well as in those of the Renaissance (Fig. 19, right half); (Pantheon, Dome of Cathedral of Florence). A peculiar mode of vaulting is shown by

the dome of the Temple of Jupiter at Spalato (Fig. 21, left half), an attempt to increase the stability of domical construction (V-l-D, IX, 473, etc.). A further possibility of dividing the surface of the dome into clearly rhomboidal (Fig. 20) ... triangular areas, whose sides in the first case form spirals on the surface, and in the other case even form meridians, has scarcely been employed, but forms the basis of many late Gothic star vaults.

Roman pot vaults were composed of especially shaped pots inserted in each other, their interspaces filled with cement concrete, and also consist of a series of pots arranged in a spiral rising from the beginning of the vault to its vertex in continually closer turns; or the pots were arranged in zones, forming circles of diminishing diameters.

A peculiar mode of domical vaulting (Fig. 19, right half) was employed to fill in between supporting arches of (Fig. 21, right half) was used in the dome of the Cathedral of Florence; bricks were set in herring-bone bond, after the dome was divided by meridians. It is clear that ornamental ground plans, as indicated in Fig. 18, may be constructed by different modes of vaulting, as in the figure. By the aid of ornamental brick bonds, of different materials, or of bricks of different colors, the most varied surface patterns may then be obtained.

38. Principle of Gothic Groin Vault.

The chief result of mediaeval vaulted architecture consists in the invention of the groin vault with supporting ribs, between which extend the compartments as domical surfaces.

Taking a simple square groin vault (Fig. 22), produced by intersection of two semicircular tunnel vaults, it is clear that the diagonal line of intersection of two tunnel vaults is a semi-ellipse. Further, that in the side or end arch, the pressure of the vault is least at its highest point or crown, and increases downward by addition of the weights of the voussoirs, attaining its maximum at the lowest voussoir and the pier; it is also clear that in the diagonal arch, the pressures on each different stone will be doubled, since the pressure from two sides combine on it. The most heavily loaded portions of the vault are therefore the diagonal arches and the piers. The voussoirs of the vault then slide outward, and this thrust is greater in the diagonal arches and on the piers; or they tend to produce rotation about the inner or outer points a b of the voussoirs (Figs. 23, 24), the fall of the vault resulting from the opening of the joint inward or outward.

For a vault to be stable, the abutment must be firm and neither slide nor rotate about an edge; it must form a homegeneous, fixed, and heavy or strongly loaded mass, much too heavy to be overthrown by the thrust of the vault. The vault must itself be so strongly constructed, that its parts are immovable, that its material may not be crushed by its own or an added load, nor cracked by too great strain at any weak points. The first condition is fulfilled by correct inclination of the joints, per

pendicular to the line along which the pressure of the voussoirs is transmitted, and by good mortar, which hinders the sliding of the stones at the joints by increasing the friction.

The fall of the vault will be prevented by its thickness and by increasing this at the points most severly strained (Art. 39). If such a vault is built of brick, the separate bricks must be wedge-shaped, or, if rectangular, the mortar joints must take the wedge form; these are then like voussoirs between which the bricks are sqeezed.

For vaults already considered, such as the Romans constantly employed, a difficulty in executing them in cut stone is caused by the necessity of arranging separate groin voussoirs along the groins (Fig. 25); were such a vault built in brick, then must the bricks be butted and mitred at the groins, forming a through joint (Fig. 26). A sharp groin could scarcely be built of rubble. In building concrete vaults the Romans could easily overcome this difficulty by excellent mortar; in mediaeval architecture under entirely different conditions, men were compelled to avoid this defect of the groin vault by a peculiar expedient; it was merely necessary ti construct separate ribs of stone or brick (Fig. 27) against which the compartments abutted, and the problem was solved in the simplest manner. But whether executed in stone or in brick, the elliptical diagonal arch was constructed with difficulty, the radius of each separate point having a different center. When all complexity of the vault is to be avoided, the arrangement of separaate diagonal ribs is only practicable if these diagonal ribs are circular arcs. The first important innovation in the construction of the groin vault was introduced in the Middle Ages by arranging semicircular diagonal ribs. But these produced various consequences; if the diagonal ribs and the side arches have a common height of springing, the keystone of the vault is higher than the crowns of the side arches by the difference of the radii of the two arches, the compartments of the vault rest most heavily on the lower side arches and cause a considerable thrust on them, and the highest part of the vault will be very dark.

A second innovation consisted in making the ridgelines of the compartments of the vault not straight but circular arcs also, so that each compartment was itself strongly curved like an expanded sail, approximating a domical surface, stronger and more immovable, at the same time loading the diagonal rib more heavily (Fig. 28).

The French Gothic always based the groin vault on the dome and treated compartments as simple domical surfaces. The German Gothic usually curved the compartments more strongly, so that their middle lines correspond to a greater radius than the radius of their cross section; it is easily seen that a greater curvature of the section is preferable for stability of the vault, for the strongly curved compartment causes smaller thrust on the ribs than if flatter. Especially in Holland, where the yielding soil required the vaults to be made as stable as possible, compartments were sometimes so strongly curved that their highest point not only rises a-

bove the keystone, but extends 25 inches or more higher. The view of these vaults is above very materially differs from that of simpler groin vaults. Such vaults are not only more stable, but are more easily executed; require no special centering, since each row of voussoirs is set by itself; and produce a strong play of light and shade, advantageous for softened internal lighting. The difficulties in the construction of such vaults will later be seen to result from geometrical peculiarities of the groin vault, and almost wholly disappear, as on the Rhine and in Holland, where the easily wrought Brohltal tufa was employed.

37. Improvements.

Endeavors were made to solve the problem by making the crowns of the side arches approximately or exactly at the same height as the crowns of the diagonal arches. This could be done in various ways; either by making the side arches elliptical with major axes vertical, as employed in some early Gothic churches (Ungew. G.C. 2d edit. p. 90), as in the Church at Wetter and the Church at Nantes; the end was thereby attained, but the difficulty was increased, since semicircular diagonal ribs were produced with perhaps two different kinds of elliptical side arches, not easily constructed. The elliptical arches could indeed be replaced by oval arches, i. e., by giving to the lower part of the arch a greater radius than that of the upper part; the purpose was better fulfilled thereby, but only imperfectly so. Or by placing the crowns of the diagonal and side arches at the same height, and the springing points of the two kinds of arches at different heights; the large diagonal arches were then set on capitals, and the side arches were "stilted" by short vertical portions, whose height equaled the difference of the radii of the side arch and of the diagonal rib.

This solution of the problem was treated in many ways; diagonal ribs were sometimes set directly on the capitals, while side arches were placed on separate small capitals of short columns resting on the principal capital, as in the Refectory at Maulbronn. At other times two forms of capitals were arranged for the two kinds of arches and also two forms of supports, so that the compound pier had capitals at different heights, the abacus of the transverse arch forming an annular band on the columns supporting the side arches, as in the porch of the Abbey at Maulbronn (1230) and in the vaults of the galleries of the Cathedral at Magdeburg, or these may be made separate, as in many buildings of the transition style and of the early Gothic. Another method was to omit the capitals of the supports of the transverse arch.

A last method remained for solving the problem, when transverse and side arches were of equal height; the transverse arch was set on the capital and the diagonal rib was permitted to intersect the abacus of the capital. An example of this unusual arrangement, already suggesting Late Gothic, is found in two choir chapels of the Cathedral at Regensburg.

All these methods have objectionable results. If the hexapartite vault was em-

ployed, greatly preferred attimes (Fig. 29), thre were three different spans of arches, or even four, since piers b for receiving the simple transverse arches were smaller than main piers a, serving to receive the cross arches and ribs, for arches of four kinds.

In the Refectory at Maultronn, diagonal ribs are semicircular arches, the small transverse arches are circular arches very much stilted, and the larger cross arches a a, b b, are pointed. Although this alternation of arches and of their curvatures makes a strong impression usually, a certain disquiet and complexity in technical execution exists in the entire system. Architects in the transition and early Gothic styles in Germany sought to remedy these evils. They were much hampered by the square form of plan; for vaulting rectangular bays, they had three different widths of span, having ratios to each other as that of one side to the other and to the diagonal, like the corresponding radii of the arches. The different heights of springing were very inconvenient, required more expensive capitals, and made the stone-cutting more complicated.

An attempt was made to bring all springings to a common level. There was the choice of spanning the longer side of the rectangle by a semicircular arch (Fig. 30) and the shorter one by a pointed arch of equal height, as in vaulting the different bays of the side aisles of the Church of S. Ulrich at Regensburg (1250); or the diagonal arches were made semicircular, the side arches then being pointed (Fig. 31). The first construction, whose alternation of differently curved arches for low vaults makes a good impression, is not advisable for high vaulted aisles of churches; the use of the pointed arch for groin vaults, already found more than a century earlier at Vezelay and S. Denis, was very slowly accepted in Germany; Heisterbach indicates a reaction against the Gothic, a desire to solve the problems of the Gothic style without its scientific expedients.

The problem of vaulting becomes more complex for trapezoidal bays in the choir aisles of churches. If the different spaces are then spanned by semicircular arches, the outer side arches a b (Fig. 32) will be larger than the inner side arches c d, the radial arches a e and b d will be alike, and may be greater, (Fig. 32) or smaller, (Fig. 33) than the outer and inner side arches. The radial vaults will then be conical vaults inclined upwards toward the exterior of the choir (Fig. 34); the vault ribs may either be simple diagonals, as in the choir aisle of the Cathedral at Langres the keystone e is then lower than the apex of the vault (Fig. 32) and the ribs are of unequal length; or the ribs may be made of equal length, when the keystone e' (Fig. 33) indeed falls at the apex of the vault, but does not form the centre of the axis f g. Finally, the apex and keystone of the vault may be placed at the centre e'' of the axis f g (Fig. 35), as usual, producing unequal arches, though not differing enough from each other, for the longer arch to crowd the shorter one towards its springing.

Viollet-le-Duc gives interesting examples of endeavors in the Romanesque style to

conquer difficulties in groin vaults over trapezoidal bays by a double curvature of the diagonal ribs (Fig. 36). Thus in the Church of Notre Dame-du-Port at Clermont, and in the Cathedral at Bourges (V-1-Duc, IV-69; IX-491 etc.). In the Church of Notre Dame-du-Port at Clermont, the radial arches are omitted and the diagonal groins are constructed without special ribs. But the entire construction thereby becomes very complicated and is executed with difficulty, each voussoir of the doubly curved diagonal groin requiring its special form. All these modes of vaulting trapezoidal bays must be termed quite imperfect in comparison with the Pointed vaults of the choir aisles of S. Denis, By the use of the pointed arch, retaining equal height of all springing points and crowns of vaults, any required form of bay may be covered.

38. Pointed Vaults.

The problem of constructing a rectangular groin vault may be treated by different methods.

First Method of Construction. The diagonal arch is semicircular, and with the same radius two pointed arches are constructed as side arches, one being depressed and the other lancet, the centres being inside the first arch and outside the second (Fig. 31).

Second Method of Construction. After more fully learning the peculiarities of the pointed arch, the two pointed arches were constructed in accordance with the same principle, but with different radii. In both cases, different heights of the side arches were obtained with the same height of springing. If these were to be made exactly or approximately equal in height, there were two modes of procedure:--

Third Method of Construction. Both pointed arches were drawn according to the same principle but with different radii, their crowns being raised to exactly or nearly the same height as the crown of the transverse arch, the different heights of the springings being equalized by stilting the arches (Fig. 38).

Fourth Method of Construction. Or lastly, the heights of springings and of crowns were made uniform, the first pointed arches being then found, which directly resulted from the given conditions.

Criticism of Methods. The first method produced a striking diversity in forms of arches but presented the advantage, that excepting the keystone and a few courses above the springing, the rib blocks and arch vousoirs could be cut by a single method (Template or Pattern). The second method produced a uniform appearance and a certain animation of the vault, yet over very narrow rectangles, there was an unpleasing result from the different radii of the arches and very great differences in the heights of the crowns; but just as such differences were often desirable, for this increasing the height of the vault towards its apex was an esthetic advantage, and by combining the second with the third method, any desired proportions of heights in the vault could be obtained. The heights of the crowns are generally located in Early Gothic on a spherical surface, constructed with the diagonal arch as a meridian curve, when the height a of the vault (Fig. 37) is laid off from both sides of the rectangle, and the

circular arcs b b and e c are described with a as radius, their intersections b b and e c with the produced sides of the rectangle determining the heights of the crowns.

The advantage of equal radii was more or less important in early Gothic, since the ribs and transverse arches generally had different profiles; but is so authoritative in the richer vaults of Late Gothic, that a single radius is almost always used. The disadvantage of different heights of crowns was generally less in pointed groin vaults, compared with round-arched vaults. Finally, the fourth method had scarcely an advantage over the others, but a defect, that as by the first, lancet pointed arches were produced, which the best German and French Gothic sought on principle to avoid. At least, the pointed arch based on the equilateral triangle was preferred to any lancet arch.

After the pointed arch had quickly gained the preference over the round arch, both on account of its slenderness, best suited to high church buildings, and also by its advantages in the form of windows, it was but a slight further advance to make the diagonal arch also pointed; this completed the Gothic groin vault with entire consistency according to its geometrical peculiarities.

39. Advantages of Pointed over Round Arch.

The pointed arch possesses over the round arch not only advantages in its geometrical peculiarities, but also has an important structural value by its more favorable conditions of stability, since it exerts a smaller thrust. It is easily seen that if we rest two bodies a b (Fig. 39) against each other, like boards, playing cards, or dominos, so that they remain in equilibrium, this may be possible if nearly vertical (No. 4), but perhaps not if more inclined, (Nos. 3, 2, 1), since they tend to slide, i.e., to exert a thrust on the supporting surface; we can prevent slipping by placing a heavy body against the lower end of each domino, such as a pile of dominos, against which the two dominos a b press. The more steeply inclined the bodies a b are to the surface, the smaller thrust they will exert, and the more nearly horizontal as in No. 1, the greater their thrust, therefore the heavier must be the abutment against which they rest. But the two halves of a masonry round, segmental, or pointed arch are similar to these two blocks or cards in equilibrium; the two halves of the pointed arch (Fig. 39, No. 3) will exert a smaller thrust than the two halves of the round arch (Fig. 39, No. 2), assuming the same span; the halves of a lancet arch (Fig. 39, No. 4) will exert a still smaller thrust, but those of the halves of a segmental arch (Fig. 39, No. 1) will be very great.

If we now compare (Fig. 40) a segmental arch, whose length is one-sixth of the circumference of a circle with radius r, with a round and an equilateral pointed arch, all of equal span, the lengths of these three half arches will be to each other as 1/8 pi r: 1/4 pi r: 1/3 pi r, or as the numbers 2 : 3 : 4; with equal cross sections of masonry arches and like materials, their weights would be to each other as their lengths. The weights of the arches increase with their rise. But the weight as a

vertical pressure, and the rise of the arch for the same span, determine the thrust.

If we now conceive the three arches a b c (Fig. 41) to be divided into infinitely thin vertical laminas, we easily obtain their centers of gravity, which are joined in a curve and represent the so-called middle line of the arch. Denote by s the point in which the middle line of the arch intersects a vertical through the springing of the arch, and this tangent will give the direction of the resultant thrust, which the weight of the half arch exerts on the abutment. But the parallelogram of forces, this resultant thrust is the resultant of the horizontal thrust H and of the vertical pressure P (weight of one-half the arch) at the point s. Lay off s p as the vertical pressure P draw the horizontal p h, whose magnitude corresponds to the horizontal thrust, which with the load P produces the resultant thrust S -- s h; Then for all three arches, we have $\frac{P}{H}$ -- cot. a, $\frac{P}{S}$ -- cos. a, $\frac{H}{S}$ -- sin. a, or since the weight is computed in a given case, the middle line of the arch and its tangent are constructed, and the angle a is therefore easily found:--

$$\text{Horizontal thrust } H = S \sin. a = \frac{P}{\cot. a}$$

$$\text{Thrust } S = \frac{P}{\cos. a} = H \cot. a$$

$$\text{Weight } P = H \cot. a = S \cos. a.$$

A correctly constructed drawing shows that with an increase in the rise, and consequently in the weight of the arch, assuming a constant width of span, the horizontal thrust remains constant and the resultant thrust increases. If for example, A B (Fig. 42) represents the middle line of the arch, and we lay off at its points 5, 10, 15 - - - the magnitudes P1, P2, P3 - - of the corresponding weights from B to 5, B to 10, B to 15 - - -, draw the tangents and the horizontals, we obtain for each point the resultant thrust as the resultant of the increasing weights and of the constant horizontal thrust.

For example, if we have to determine the thrust of a Gothic grain vault, whose compartments are themselves curved and are not cylindrical but domical surfaces, the each half rib A B supports the weight of the two half compartments a A B, A b B, of plan (Fig. 43). This weight is easily found for any given construction; lay off for each point of the diagonal rib the weight of the compartment corresponding thereto, and represent the upper line of this loading in elevation in Fig. 43, and which rests on the rib A B; then divide the entire figure in vertical laminas, which are halved to find the centre of gravity of each strip; join thses centres of gravity in a curve, the middle line of the arch, which cuts at s a vertical through the springing, and to each point i of the middle line of the arch, then corresponds as a vertical pressure the weight of that portion of the arch lying between it and a vertical drawn through the crown of the arch. The load is least at the crown and greatest at the springing of the arch. If the loads P be laid off in correct proportion to each other for each point of the middle line of the arch, the tangents drawn at those points, and the horizontals p h drawn through the ends of the load

magnitudes, the angles are then found and the quantities P, H, and S may be computed.

If in an arch the single voussoir A be set on the one next below it (Fig. 43 a), its weight makes it tend to slide down on the joint. If we conceive its weight to act vertically at its centre of gravity s, the resultant thrust s h acts perpendicularly to the joint, s p is the load, and p h is the horizontal thrust. The voussoir is in equilibrium, if it can neither rotate nor slide; the entire arch composed of voussoirs is in equilibrium, if each of its voussoirs can neither rotate or slide. The voussoirs are assured against rotation, if the lines of action h of the pressures acting on them passes through their centres of gravity (Fig. 43 a); if the pressure acts on them elsewhere, a rotation in a positive or negative direction around the centre of gravity might be possible. A rotation also becomes impossible if the line containing all pressures, the line of pressure or support, coincides with the middle line of the arch. The possibility of the sliding of a voussoir disappears, if the pressure acts normally at the joint, when the possibility of the sliding of two stones on each other is equally great in all directions. The line of pressure or support indicates at each point of the arch by its tangent the direction of the pressure, resulting from the separate forces acting on the arch, and likewise gives the pressures, which each section of the arch must withstand by the resistance of the material to crushing; in practice arches are mostly circular and the radii of the joints point toward a centre. The line of support does not then coincide with the middle line of the arch, but should vary therefrom the least possible. If the arch be uniformly loaded by an equal weight per unit of length, as for an ordinary chain, the line of support assumes the form of the common catenary curve. The line of support may be accurately calculated in any given case or be found by geometrical construction.

The effect of the conditions of loading of a vault may be made clear to any one by a simple experiment: two heavy objects are laid on a table, for example two books, and a sheet of cardboard (or playing-card) is placed between them, taking the form of a line of support (Fig. 43 b); if the crown of this be loaded by pressure with the finger, it sinks down and the curve bends out sidewise (Fig. 43c)k and finally the crown falls in. By loading a semicircular arch of masonry, the line of support is in like manner bent outwards and approaches the extrados at b b (Fig. 43 d); not only will the pressure in the arch at b no longer be normal to the joint, and a sliding of the voussoir therefore becomes possible, but at b the line of support will tend to produce rotation in the direction of the arrows, i.e., to compress the point b more strongly than any other part of the joint; the joint may then open outwards, (Fig. 43 d), or the material may be completely crushed at this point and the fall of the arch will then occur.

The points of rupture b b fall at about one-half the height. If the loading were so great as to cause the line of support to sink (as at c, Fig. 43 e), this joint would open inward and the arch would break into four pieces. The line of support is a cat-

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enary for uniform loading, but more nearly approaches the middle line in a pointed arch (Fig. 43 f), so that the pointed arch is therefore more suited for the arches of loaded vaults. If the former experiment be repeated by bending the cardboard in a pointed form and loading its crown, the arch takes the form in Fig. 43 (dotted line), and the points of rupture fall at about one-third the height. The pointed arch not only supports a heavy load at the crown without causing the line of support to vary t. much from the middle line of the arch, but it actually requires a heavy load at the crown, such as could not be expected for a segmental or round arch, since the weight of the sides of a pointed arch of masonry tends to force the spandrels together and slide the keystone upwards, as made plain by Fig. 43 g. Every one knows by experience, who has ever built a pointed arch vault, that the crown of the vault must be very heavily loaded before removing the centering, and also, that in old vaults, their loading by rubbish or masses of masonry set on their crowns cannot be carelessly removed without introducing a change in the conditions of the loading of the vault, which may act dangerously. To avoid the danger of fracture in the arch at b b, this is backed up by horizontal courses one-half the height of a round, or one-third that of a pointed arch.

To construct a line of support, divide the arch (Fig. 43 h) and loading into vertical laminas of equal width b. Let P1, P2, P3 --- P n weight of each separate vertical strip. Let a1, a2, a3----an be the angles between a vertical and line of support in each strip. Let s be the point in which line of support cuts a vertical at abutment; then retaining same notation: P -- p1 + p2 + p3 + --- - - - - pn.

H -- $P\frac{z}{y}$, y being rise of crown of the line of support ~~through~~ point of intersection s, and z distance of centre of gravity of arch with loading from vertical through SA; hence $\frac{y}{z}$ - tan. a.

Direction and magnitude of resultant at any point of line of support may be obtained by constructing parallelogram of forces with constant horizontal force H and the vertical force = p1 + p2 + p3 + --- force = P at the crown, and magnitude of the horizontal resultant there = H. To the angles a1, a2, a3 ---- an, correspond the tangents, tan a1 -- $\frac{p1}{H}$; tan a2 -$\frac{p1+p2}{H}$, ----- tan an -- $\frac{p1 + p2 + ----pn}{H}$. Taking a horizontal through crown of arch as origin of abscisses, lay off ordinates downwards; then let yn = ordinate, and y n = tan a1 + tan a2 +---- tan an. If line of support does not coincide with middle line of arch, then must the form of arch be changed until this occurs.

If a room with three aisles of equal height and unequal widths is to be vaulted, and lancet arches are to be arranged over side aisles, their keystones must be heavily loaded, since the side aisles will be crowded together by the middle vault. In the Church of S. Martin at Landshut in Bavaria, this was so arranged that by peculiar construction of framework of roof all the keystones of the

vaults were directly loaded. In the lower story of the S. Chapelle in Paris, special flying buttresses were placed at about one-half the height of the centre aisle to receive its thrust (V.l-Duc, I-78; IV-476). The simplest solution of this problem consisted in loading the keystone of the vault by masonry, or changing it into a pendant keystone, permitting it to extend down far below the crown of the vault. Loading the keystone with a mass of lead was also sometimes employed.

40 Richer Treatment of Early Gothic Vaults.

After the introduction of the pointed arch, not only were vaults possible over any required regular or irregular form of plan, but also a richer treatment of vaults.

Triangular Vaults.

Triangular vaults are not rare in early Gothic; we first find them in the early Christian Cathedral at Aix-la-Chapelle; in the choir aisles of Notre Dame at Paris and at Chalons, such triangular vaults are consistently employed in the form of simple compartments extending between side arches. (Figs. 45, 46). A second method of vaulting, preferably used in Gothic, treated the vault as an actual triangular groin vault (Figs. 47, 48); the most complete example of the arrangement of a plan on the basis of triangular bays, (Fig. 49), is in the chapter hall of the Monastery of Eberbach in Rheingau, as well as the Romer at Frankfurt-a-M. (Ungew. p.96; V-l-Duc, I-288).

Hexapartite Vaults.

In the plan with middle aisle in square bays, each corresponding to two bays of the side aisles, piers a a were stayed by the arches of the vaults, but piers b b, had to resist the thrust of the vaults of the side aisles, and must either be made too great in depth (as shown in Fig. 51), or this thrust must be opposed by a thrust in the opposite direction, Piers b b then being likewise connected by an arch. The hexapartite vault was thus produced, first used in the Cathedral at Noyon (1150-1190), then in Notre Dame at Paris, in the Cathedrals at Laon and Bourges, in the Church at Mantes; in Germany it was made the basis of vaulting in the Cathedral at Limburg. In the last three churches, piers b were made thinner than piers a, since the former were to take the thrust of only six, and the latter, of eight ribs and transverse arches.

Also in many 3-aisled transepts, as in the Cathedrals at Paris, Laon, and Beauvais, hexapartite groin vaults necessarily appeared. (Fig. 52). One of the most beautiful rooms with hexapartite groin vaults is the refectory of the Monastery of Maulbronn; (Fig. 53; the diameters of the round piers also alternate here, intermediate ribs are consistently carried along the ends of the room also, and intermediate buttresses are omitted. In many

cathedrals, like those at Paris, Noyon, Bourges, Sens, Troyes, Rouen, Narbonne, and at Alby, as well as in many German churches, the hexapartite vault was well suited to oppose a contrary thrust to the thrust of the ribs of a choir vault at a by means of the ribs a b; in many other churches those half-hexapartite groin vaults were omitted, since the compartments a b c (Fig. 55) securely held the arch b a b and prevented yielding sidewise.

Octapartite Vaults.

Octapartite vaults are not rare in the early middle ages of France; in provinces where domes had eight ornamental ribs, it would be easy to change those domes with eight ribs into octapartite groin vaults. But in Gothic, that form would be occasioned by a requirement, and the octapartite groin vault necessarily results from arrangement of vaults in the towers of the Cathedral at Paris. The crowns of these vaults (Fig. 56) receive both the intermediate transverse arches of the hexapartite vaults of the middle aisle, and also the longitudinal arches of the double side aisles, as well as the vault ribs. In the Cathedral at Cologne, whose plan is an extension of those at Amiens and at Beauvais, and whose middle aisle is covered by rectangular groin vaults, this necessity for octagonal groin vaults in the towers disappears, and a pier occurs instead of the keystone a; in place of vault with eight ribs, there are four ordinary groin vaults with two ribs each. Octapartite groin vaults are further employed over the intersection, so that besides four diagonal ribs, four crown ribs are arranged, as for the intersection in the Cathedral at Laon.

Polypartite Vaults.

In the vault over the intersection in S. Maclou in Rouen, an octapartite groin vault, the crown is also marked by special ribs, so that the plan of the vault is divided into 16 parts. Vaults divided by 16 ribs also cover the middle aisle of the Romanesque Pfarr Church at Boppard, rebuilt (1212-1242) in the Rhenish transition style (Fig. 57). A decapartite groin vault covers the interior of the Church of S. George at Cologne.

Ornamental Vaults of Early Period.

A most beautiful Early Gothic vault of rich design (Fig. 58), which does not appear at all in France, is found in the sacristy of the Cathedral at Worms and in a beautiful private chapel at Regensburg, the "am Romling" (Villars de Honnecourt included this in his Sketch-Book; V-l-Duc, VIII-4). From a central pier diagonal arches extend to the angles of the square, but the compartments of the vaults are divided into smaller spaces by a system of ribs, each being separately vaulted. Such a construction approximating Late Gothic vaults, from the latest middle ages, is found in the Castle of Ronneburg near Gelnhausen.

41. Improvement in Method of Vaulting.

With the introduction of the pointed groin vault also came an improvement in the mode of vaulting. If the courses of voussoirs were arranged parallel to the axes of the vaults as before (Fig. 59) and each course was itself curved, so that the entire vault was curved upward, a wedge or lens-shaped space must necessarily occur at the crown of the vault (Fig. 60), very hard to close. This might be avoided if the compartments were vaulted diagonally (Fig. 61). For a vault rib was then formed above the stone rib by interlocking the voussoirs themselves (Figs. 62, 63), against which the compartments abutted, and strong enough to support the vaults.

This vaulting in courses normal to vault ribs and side arches first occurred in the English Cathedrals at Ely and Westminster (1220-1230), and was transferred in Norman buildings to France. At the crown of the vault, the Voussoirs join in herring-bone bond (Fig. 64), and the stone ribs become unnecessary and merely serve as centerings, facilitating the free hand vaulting of the compartments.

Ornamental Vaults in the Best Gothic Period.

To construct the compartments of very large vaults without centering, it is necessary to arrange intermediate ribs (Fig. 65), solidly constructing them of stone and connecting them by a keystone. A richer treatment of the vault was thereby produced. When this step had been taken and the richer appearance of the vault been acceptrd as satisfactory, it was easy to subdivide all vaults by a system of ribs into smaller compartments, separately vaulted, thereby producing the infinite abundance of Late Gothic ribbed vaults.

Such ornamental groin vaults first came into use for covering the intersection in the Cathedrals at Amiens, Beauvais, Narbonne, and Clermont; omitting diagonal ribs, we find the vault employed in the Abbey Church at Heisterbach. The German Romanesque style preferred to cover the intersection by octagonal groin vaults (Figs. 66, 67, diagonal section), but set diagonally to form special pendentives at the angles, above which we occasionally find a transition from square to octagon; in France, the intersection in the Cathedral at Coutances is covered by such vaults, and the Cathedral at Mentz in Germany. The Romanesque style also usually covered the intersection by octagonal cloister vaults with or without pendentives, according to whether the intersection was square or octagonal plan.

These ornamental groin vaults were especially appropriate where instead of a keystone, a ring- key-circle of considerable diameter was arranged, (Fig. 68), for hoisting bells in church towers, building materials, water, etc., through vaults over intersections or other parts of churches. When

this consisted of eight voussoirs, eight ribs would be required to press them towards the centre.

An ornamental groin vault may also be derived from the plan of the polygonal choir; in the simplest case (Fig. 69), if the choir consist of five sides of an octagon, it would be likely for the prolongation of its ribs beyond the keystone at a b to be repeated at b c and c d; thus produced a system of ornamental groin vaults, as in the two-aisled Church of S. Sphia at Dresden. Or choir vaultsware decorated (Figs. 70, 71), thereby obtaining a new system of ornamental groin vaults, as forthe outer aisle, producing an infinite choice of possible vaults, which might be further enriched by using as a basis for the vaults three or four sides of the hexagon, five sides of the decagon, etc., instead of five sides of the octagon (briefly, 5-8 choir ending). Variations of these ornamental groin vaults, favorite in German Gothic, were further developed in secular buildings, such as halls of dwellings, where the problem was to unite two sides divided into different numbers of bays; there are halls of houses in Landshut, Bavaria, ornamental groin vaults with five bays on one side and six on the other. (Beit. Taf. 54, Figs. 15, 16; Chap. 9; Ungew. p. 144).

42. Ornamental Groin, Star, and Net Vaults.

The groin vault, like the tunnel or domical vault, could be made the basis of these ornamental vaults, since the plans of these vaults were divided in compartments by a network of lines, constructed in stone as a system of ribs, and the compartments were vaulted between these. Thus were produced the ornamental groin vault, the star vault, and the net vault. With diagonal vaulting, the ribs and arches were indispensable to stability of the vault, yet no difference between profiles of ribs and of arches was now required, and all sections could be made alike; also with these ornamental vaults, pointed arches were no longer required; all keystones of the vaults lay on cylindrical or spherical surfaces, and the ribs could all be cut to one radius, as almost always inferred in ornamental domical vaults, and likewise preferable in ornamental groin and net vaults, since one must otherwise have recourse to the elliptical or oval arch. The entire science of stone-cutting had thus been reduced to similar ribs and grouped similar keystones, with special impost courses, thereby simplifying the vaulting.

Ground-plans, like those of the tower vaults of the Cathedrals at Frankfurt and Strasburg (Fig. 72) may be vaulted in various ways; either the points a b c d e not only lie in a spherical surface with a diameter equal to diagonal of the polygon, but also ribs a b, b c, c d, d e, which then have different radii, for to horizontal projections a b, b d, correspond ribs with the diameter a f, to rib b b corresponds a diameter g g, and to

rib d e, the diagonal of the polygon; on this principle are choir vaults generally constructed (Figs. 73, 74). (Church of Prüll near Regensburg). Now if a common radius for all arches was desired, this might be less or more than half the diagonal of the polygon; in the first case, all ribs would be strongly curved and compartments would be strongly convex, in the latter, ribs would be less curved and compartments flatter, than a spherical surface with a radius of the half diagonal of the polygon. This may easily be seen by the diagram (Fig. 75) from Fig. 72. a i, b i, c i, d i, e i, are the distances of the horizontal projections of the intersections of the ribs from the horizontal projection of the apex of the vault. When a i, half diagonal of polygon, is taken as radius of the spherical surface, there correspond the height points 1, 2, 3, 4, 5. In both cases, assuming a radius more or less than half diagonal of the polygon, the arches a 1 would not be tangent to a vertical at the springing of the vault, and this would be unstable in practice. In England and the Netherlands for very flat vaults, the Tudor or oval arch was by preference employed for ribs of vaults.

Second Method of Construction; First Example.

A second method of construction for ornamental ribbed vaults consists in not placing all keystones in the surfaces of groin, tunnel, or domical vaults, and for groin vaults, in not taking the half diagonal as radius of ribs of the vault, but a greater radius, found by laying off horizontal projections a b, b c, end to end (Fig. 76). These vaults are termed serial, and arches with the radius a b + b c are principle arches. The points b and c now lie in vertical projection (Fig. 77) on a spherical surface with radius a b + b c. But ribs a c with like radius intersect at a' the vertical erected at the springing. If it be desired to arrange arch a c of the plan to pass through the springing a and the apex c' of the vault, it is only necessary to locate the intersection d with the chosen radius from a and c' as centres (Fig. 77), then describe from this the arc a c' this then intersects obliquely the vertical at springing. Only when another radius is assumed for the diagonal rib, corresponding to a pointed arch, may an arch be obtained, tangent to vertical at springing.

Second Method of Construction; Second Example.

Let a b + b c + c d be radius of the principal arch (Fig. 78). The height of apex of vault is the same, and to the horizontal projections a', b, c, d, correspond the vertical projections 1, 2, 3, 4, (Fig. 79). The choice of principal arch by the method of series is always somewhat fanciful, for any other radius might have been taken, greater than a b + b c + c d.

The crowns of side arches may be fixed in various ways; any round or pointed arch may be erected over the side of the octagon against which the

compartments abut, or a e may be laid off on the radius and the height e 5 be taken for the height of the crown, or as not unusual, the crown is made higher than the point 5, so that the compartments rise from point 5 towards the wall. A few examples in drawing these series with principal arches will not only enable one to construct the most complex Late Gothic vaults without difficulty, but also to make accurate drawings of existing vaults by the aid of a plan and the principal arch. These vaults based on the principal arch certainly appear much more animated than ornamental vaults, derived from the groin, tunnel, or domical vaults.

Of these ornamental vaults, a series of which is given by Ungewitter in his "Lehrbuch" (Manual of Gothic Construction), to which I have added other specimens in my "Beiträge" (Contributions to Knowledge of Mediaeval Architecture in Germany), a few pleasing and interesting cases may be cited. Those in Fig. 80 are in the Archives of the Cathedral at Mentz. Another peculiar vault is over a side chapel of the Cathedral at Prague (Fig. 81); such a plan may be treated variously in elevation, according to whether lines a b, c d, e f, or a series be taken as radius of principal arch. A most graceful ornamental groin vault, from the polygon with 16 sides, is that in the choir of the Monastery at Prüll near Regensburg. The construction of the vaults here determines the widths of the bays.

Net Vaults.

For the net vault, the distance a c (Fig. 82), or the half diagonal, is generally taken as radius of principal arch. The intersections of the ribs in the first case lie in elevation at points 2, 3, 4, 5, of the verticals b 2, c 3, d 4, e 5. Arches h e and h g fall from 2 towards 3, since height above h equals height at 3. Height of the side arches f g may be fixed according to whether windows are to be high or low.

Since vaults arched parallel to ribs do not longer require transverse arches, these are omitted in simple groin vaults, as in the Church at Deggendorf in Bavaria (Fig. 84), or in ornamental groin vaults as indicated in Fig. 85, as commonly employed in the late middle ages. In the side aisles of the Church of S. Agatha at Aschaffenburg is a peculiar arrangement of the simplest net vaults, produced by throwing a circular arch from a pier to the second one opposite. Intersections of ribs now lie on a tunnel vault, whose generating curve is a semi-ellipse with major axis vertical. If this simple network of ribs be repeated in a second interposed series, a most frequently employed net vault is obtained (Fig. 86); since the arch a b is then a semicircle, the crown e of the rib c d is at the same height as the crown f of the rib a b, and since c d is only half as long as a b, connecting ribs a c, d g, must either be struck from keystone d over d with same

radius to g on plan, or from d' to a' in elevation (Fig. 87), when centre of the circular arc is at d 2 on prolongation of the line d d'.

As seen in oblique view (Fig. 88), only points 2, 3, 4, 5 (Fig. 88) may now be connected by a compartment; points 1, 2, 3, form a vertical dividing surface. The section 2, 3, of the compartment 2, 3, 4, 5, with division surface 1, 2, 3, may be replaced by a new rib and the division surface be itself omitted, in case rib 1, 2, alone remains, or it may be filled and decorated by tracery. This motive is found in the cloister of the Church of S. Stefan at Mentz (Ungew. Fig. 278 b). Such vertical division surfaces arose in a peculiar way in the vaults of the western choir of the Church of S. Katherine at Oppenheim (Fig. 89); a f + f c is radius of principal arch; c f and e b are projected in elevation (Fig. 90) as c' f' and c' b' d' d' correspond to d d and lie higher than f' b', but arch over a d g from d' intersects at g' the vertical above the springing. We here obtain vertical surfaces 1, 2, 3 (Beit. Taf. 11, Fig. 51 and text).

If in a room with triangular groin vaults the diagonals be omitted, peculiar net vaults are produced (Fig. 91), transformed by doubling into hexagonal star vaults. Thus the sculptures in the cloister of the Cathedral at Würzburg are covered by vaults. From the ground-plan of this triangular groin vault arises a new series of possible net vaults (Fig. 92), used in the most diverse places.

In the vaulting over the belfry of Gothic church towers (also for small chapels, as in Church at Ferte Bernard near Le Mans), instead of vaults, horizontal ceilings were employed, supported by ribs. Then as in the tower vaults at Frankfurt-a-M. and Strasburg, short columns were set on the keystones of the intersecting ribs of the vault, supporting the horizontal ceiling, or on the ribs themselves were placed perforated walls of tracery, as in the tower vaults of the Cathedral at Freiburg-i-B. (Ungew. Fig. 279). At the Church at Ferte Bernard (V-l-Duc, IV-122) small columns, connect with arches beneath them and support the coffered ceiling, and are set on the vault ribs; lastly, at the angles of the Church of S. Katherine at Oppenheim, the interspaces between supporting ribs, ceiling, and angles, were filled by the simplest forms of tracery (Beit. Taf. 35, Fig. 1).

43. Latest Problems in Gothic Vaults; Sports.

Further progress in the mediaeval science of vaulting was no longer possible.

Cell Vaults.

In northern Germany, cut stone was procured with difficulty and bricks of excellent quality existed, thus stone ribs were usually omitted (Fig. 93); since bricks were suitable for the construction of a rib, and spherical com-

partments were replaced by triangular and square cloister vaults. The Castle at Meissen everywhere exhibits these cell vaults. We must regard certain apparently complex vaults in Late Gothic as merely sportive, where instead of a single rib, doubled ribs of different radii are employed to produce a rich effect (Fig. 94), as in a side aisle of the Church of S. Leonhard at Frankfurt-a-M. This is objectionable for structural reasons, since the lower rib opposes and neutralizes the pressure of the upper rib.

Ribs Curved on Plan.

An extreme result of Late Gothic vaulting could be produced by curving ribs on plan (Fig. 96), the spiral series, then usually transformed into mere forms of tracery. Another sport is in Ungewitter (p. 148) from the Church at Langenstein, where two entirely separate systems of ribs are arranged above each other, the compartments of the upper system being seen through the lattice-work of the lower one, as in Fig. 95. (Ungew. Fig. 280). Late Gothic sometimes decorated ribs of vaults by foiled arches, as in a chapel in a side aisle of the Cathedral at Mentz.

The spiral series, (examples in my "Beiträge (Tat. 54, Fig. 14; 55, Figs. 14, 15), already appears in combination with straight ribs and tracery quite early in the best period of Gothic, as in the sacristy of the Cathedral at Regensburg; like foiled arches, they require the use of more material, than do simple ribs, but compose the most graceful forms.

Comparison of Late Gothic with Roman Vaults.

Thus in mediaeval architecture a series of the most diverse forms of vaults result from combination of the dome with the groin and tunnel vault, which may be used on the most diverse plans, and a single principle makes possible an inexhaustible wealth of forms. These ornamental vaults are very closely allied to Roman vaults with coffers, like those in the Pantheon and in baths; but they have an advantage over Roman vaults as the ribs almost always form a system of self-supporting triangles, whose light panels or compartments might with good mortar have been as easily changed into coffers, as those in Roman monuments. The pointed arch was in Late Gothic ribbed vaults almost entirely confined to the side arches, and was superfluous in the vault itself.

The segmental arch came into use rarely in Romanesque, chiefly in secular architecture, as at the Castle of Barbarossa at Gelnhausen for a discharging arch, and sometimes for the same purpose over church doors. It is indeed not entirely disused in Gothic, but only exceptionally employed. The Late Gothic found it tasteful and liked it, especially in secular architecture. Late Gothic vaulting generally required segmental ribs and compartments of vaults, and in secular architecture this need was increased by the

small height of rooms. The segmental arch was usually made 1-3 or 1-4 of the circle, more rarely 1-6, or with even a smaller rise. As an example of the segmental arch vault in secular architecture, is the court of the Castle at Stuttgardt, entirely Gothic in principle, and the court of the Innzum-Hirt at Steyr in upper Austria, with loggias in three stories above each other (Beit. Taf. 47, F 3).

The development of the mediaeval vault, as here briefly outlined, only occurred in general. If structural problems had played the chief part, then would vaulted architecture have been freed from all restraints, and striving for piquant effects and sportive fancies would have controlled the architects. Rich Late Gothic vaults in Austrian buildings may be found in Helfert, Atlas Kirch. Bau., also in Wien. Bauh.

44. Italian Vaults.

Northern mediaeval architecture, compared with Italian architecture, laid greater stress on height of interiors than on their magnitude and spaciousness; vaults of the central aisles of its choirs seldom exceed spans of 50 feet; great vaulted rooms could be constructed in the middle ages when required, as shown by the Karlshofer Church at Prague, an octagonal interior covered by a domical star vault of about 77 ft. span. Italian mediaeval architecture contributed scarcely anything to improve the science of vaulting; it was content with the less developed forms of Roman vaults, and usually produced its spaciousness only by exchanging effect for plainness and emptiness, by the aid of tie-rods at imposts of vaults, and by greater dimensions of structural parts.

Comparison of Northern Mediaeval with Italian Art of Vaulting.

Boldness of construction of a vault depends on three things; on its span, on section and height of piers, as well as on thickness of vault itself: lastly, on massiveness of its abutments. If Italian vaulted construction is praised for boldness, like the Cathedral at Florence with its centre aisle 80 ft. wide and moderately large piers, we should not forget that churches like S. Martin at Landshut and that of Karlshof at Prague are not inferior to Italian in boldness; the first is a 3-aisled narrow hall church with very slender piers and an enormous height, and the second is very spacious, though both have very weak abutments.

The principal endeavor of Italian mediaeval architecture and of the Renaissance in the art of vaulting is almost always devoted to the development of the dome over the intersection and in central buildings, the first of these scarcely exceeding the clear span of the centre aisle in northern mediaeval architecture, and the last being usually rare during the Gothic period. Large towers over the intersection were in the Gothic period only

intended in the Cathedrals at Regensburg and at Passau.

Italian Gothic led to the great dome over the intersection in the Cathedrals at Pisa, Siena, and Florence, as well as in S. Petronio at Bologna (Lubke, p. 628), which in the Renaissance found its highest development in the Cathedral at Florence and in S. Peter at Rome, far surpassing all Roman works. The Renaissance excelled the Romans in boldness of construction, but not Gothic vaulting in technical cleverness. Had Renaissance masters been acquainted with the simple and appropriate principle of Late Gothic ribbed vaults, applicable to the three basal forms of vaults, they must have appreciated its advantages over the heavy Roman vaults; had they desired to replace the ornamental effect of Late Gothic vaults by the effect of quiet surfaces, they could have executed their domes in accordance with the Gothic principle. But the Renaissance has the single advantage over the Italian Gothic in that it never produced in its spacious vaulted interiors the effect of plainness and bareness; it understood how to richly subdivide interiors, and to make them appear even larger by variety in decoration than in reality, excepting in S. Peter in Rome, which is larger than it seems to be.

SECTION III. SUPPORTS OF VAULTS.

45. Ribs and Transverse Arches; Keystones of Vaults.

General Remarks.

Supports of vaults are primarily ribs and transverse arches; the parts of these especially worthy of consideration are keystones and impost stones. The actual support of vaults are columns and piers. The structural parts, which resist the thrust of the vaults, are buttresses and flying buttresses. We have first to treat ribs, their keystones and impost stones, then columns and piers, lastly buttresses and flying buttresses.

Decoration of Ribs.

Ribs and transverse arches, whose sections will be considered later, are mostly plain and not decorated. Yet about 1200, ribs occur in England and in Germany, where decorated alternate with plain voussoirs, as at the Cathedral at Puy-en-Velay (V-l-Duc, III-251), or like the ribs of the choir vaults of S. Jacob at Regensburg, where square pearl-headed flower rosettes, connected by similar bands, decorate the soffit of the rib (Fig. 97) (Beit. Taf. 53, Fig. 171). Sometimes, as on transverse arches of vaults of the Refectory at Maulbronn, rounds of the section of the arch are separated by nail-head bands (Fig. 98.) (Beit. Taf. 52, Fig. 1). In very late Gothic buildings, rounds are indeed decorated in imitation of trunks of trees (Fig. 100). Rounds of transverse arches in some buildings in Rhenish transition style are treated in a peculiar way, short columns of slate being separated from each other by band mouldings of trachyte or other stone (Fig. 99). These annular mouldings always indicate on the Rhine and in Germany 1200 to 1250.

Gothic leaves ribs and transverse arches plain; Late Gothic decorated them occasionally by the cusped arch on Fig. 98, as in a chapel of the side aisle of the Cathedral at Mentz, and German Renaissance also used pearl-beads and egg-and-dart mouldings, as in the choir vaults of the Monastery at Prüll.

Construction of Keystones.

The keystone of vault ribs at their intersection is produced by drawing through their common points a l a b of the plan (Fig. 101) the radial joints a' p' and b' O' on elevation (Fig. 102). The distance P' O' then gives the greatest width of keystone and the dimensions of the stone for it. Such a keystone in oblique projection is shown in Fig. 103. When ribs intersect each other obliquely, the keystone is considerably larger (Fig. 104), since the distance a b on the plan will be greater than for ribs intersecting at right angles, and this is also true for keystones of hexapartite or octapartite groin vaults, while for tripartite groin vaults the keystone will relatively be smallest.

Keystones forming an intersection vousseir of vault ribs (Fig. 105) are

avoided in best Gothic, since they have little characteristic effect and require an unnecessary cutting away of the stone. But they were very much used in Late Gothic ornamental vaults. The intersection of the ribs is usually replaced by a cylindrical boss (Fig. 106) against which the ribs abut; ends of the ribs are then worked on the keystone in the solid.

Decoration of Keystones.

The motive of ornamentation of the keystone results from the decoration of the intersection of the ribs and also from the loading of the keystone and consequently of the vault, when it is permitted to project below the vault ribs. Late Romanesque either treated the keystone by concealing the intersection of the ribs by a rosette of leaves; first on the vaults of the Abbey at Vezelay (1130) combined with sculptures, also on the Abbey at Altenzelle, (1162-1197) or by large bosses pendant from intersection of the ribs, basket-like and with rich foliage, as a keystone at Altenzelle and several very beautiful ones in the Cathedral at Mentz (Beit. Taf. 3, Figs. 27° 28°, 28); a third form occurs at Altenzelle, consisting of a disk, placed beneath the intersection of the ribs and decorated by Romanesque ornaments; a fourth is found in the Monastery at Arnsburg near Wetzlar, consisting of a ring dropped considerably below the ribs, otherwise profiled like them and decorated by a rosette of leaves. Among the variations in treatment of keystones are those with a square nucleus (Fig. 107), and those in which this is profiled like the ribs. Very beautiful examples are found in the Rittersaal of the Castle at Vayda Hunyad in Transylvania (Wiener Bauhütte). This nucleus sometimes takes another form, as well as the decorated disk suspended beneath the vault ribs. Forms of such keystone-bosses shown in Fig. 108 are not rare.

Perforated Keystones.

The keystone is usually perforated for suspension rod of a chandelier or changed into a large ring of voussoirs, as in the vaults of towers or in vaults over intersections, for hoisting building materials.

The great ring keystones of tower or intersection vaults sometimesmerely repeat the profile of the ribs on the inside of the ring, or change the profile (Fig. 109), and are more frequently cut plain on the inside, as in the keystones in the towers of the Church at Friedberg (Fig. 110).

Development of Keystones in France.

In France, (V-l-Duc), the Burgundian type, that of Isle-de-France, and that of Cluny, have especially developed the sculptured ornamentation of the keystone; graceful foliage and symmetrical representations of all kinds were employed; yet these keystones of the 12 century were commonly not treated in correct proportion to the height of the interior of the church, and did

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not produce a proper effect. Only in the 13th century were the keystones strongly treated to produce a suitable effect at a considerable height. The keystone was not always carved before setting, partly for lack of time, partly to not injure the sculpture in setting; it was then perforated and ornaments carved in wood were afterwards attached, as in the lower chapel of S. Chapelle in Paris (1240. V-l-Duc, III-269).

Keystones in Perfected Gothic.

The perfected Gothic preferred to treat the keystone as a circle with a section like that of the ribs, while the disk-like sunken lower surface was decorated by various foliage ornaments, sculptured figures or heraldic shields, and suspended from the apex of the vault ribs (Fig. 111); short endings of vault ribs were then worked on the keystone(beit. Taf. 8, Figs. 28, 29, 30).

Keystones in Late Gothic.

Late Gothic often decorated keystones by tracery and even shaped them like suspended canopies of tracery, like the keystone of a chapel in the southern side aisle of the Cathedral at Mentz.

Pendant Keystones.

Pendant keystones, which drops much below the vault, already occur in Late Romanesque and in the transition style; interesting examples are found in the Templars' Church at Bacharach; another kind of pendant keystones is found in the Church of S. Katherine at Oppenheim, and in Late Gothic in the Church at Pirna; they were especially transformed in England into complete pendant vaults. In Late Gothic ornamental vaults, corresponding points were often decorated by similar keystones, so that different kinds of keystones came into use. Thus in the beautiful choir vaults of the Monastery at Prüll near Regensburg, a rare and instructive example of a Gothic net vault entirely executed in Renaissance forms, principal keystones are treated as pendant rosettes, keystones of a second rank as lions' heads, and the third rank are ornaments. Surfaces of compartments are adorned by delicately profiled reliefs in stucco and by angel's heads.

Keystones of Late Gothic Ornamental Vaults.

Construction of keystones of late Gothic ornamental vaults may either be very complex, as in the plan in Fig. 112, which requires 5 different keystones, all with different dimensions, directions of ribs, and mode of junction. Ribs most commonly intersect as shown in Figs. 113, 114, so that to correctly construct the vaults, the keystone must be eased off according to dotted lines a b (Ungew. p. 160, Fig. 309 a).

Extrados of Vault Ribs and Keystones.

In regard to the treatment of extrados of vault ribs and of keystones, an upper rebate on the ribs is sometimes used as an abutment for the compart-

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ments, carried around the keystone as a nucleus (Figs. 115, 118). On the ribs at Altenzelle (Fig. 117), grooves b c are cut in this rebate to receive an inserted iron anchor. On the butt joints of the ribs channels d are usually cut, branching below, and filled with melted lead (Fig. 118).

Ribs of Brick without Keystones.

For vaults where brick construction is necessary, if the ribs are also of brick, keystones are omitted; thus in the cellar vaults of the Abbey at Middelburg in Zealand in Holland, (about 1250), one round-arched diagonal extends through the intersection and the second rib with the same Profile abuts against the first rib; the cavities at the intersection of the two ribs being filled with mortar. The simple round or pointed arch remains in mediseval architecture without any decorated keystone; only exceptionally is this rule broken.

46. Form of Imposts of Vaults on Plan.

Ribbed Vaults with Longitudinal and Transverse Arches.

Conclusions on the treatment of impost blocks or abutments will be reached by the following brief consideration. Assume a square room with groin vaults consisting of four bays in plan (Fig. 119); then will the four vaults rest on two transverse arches a a, two longitudinal arches b b, four pairs of intersecting ribs c c, and eight wall arches C b. Arches and ribs transmit the weight of the vaults to a central pier A, to four wall piers C, and to four angle piers B. Wall arches C b support the least Part of the total load, each bearing 1/16, each rib carries 1/8, and the transverse and longitudinal arches each support 1 / 8. At angles B, vertical loading and thrust of two half compartments unite, at point c C are those of four half compartments, and at centre A is vertical loading at eight half compartments. Piers C are therefore made half as large as central pier A, and twice as large as angle piers B; the same Proportions to be employed for sections of wall arches, of ribs, and of longitudinal and transverse arches. If a square Profile be taken for the ribs, then will ribs, wall and main arches be formed as in Fig. 120 a, b, c, and angle, wall, and central piers naturally take the form in Fig. 121 a, b, c, in case ribs are to be entirely separated above the imPosts. These piers occupy much space and require much labor in cutting the stone. They may be simplified by giving them the smallest projection possible from the wall, and by assigning to the central pier the least possible section. Thus by gradual reduction of masses of piers, by junction or combination of main arches and ribs with a corresponding increase of their spans, forms of section are obtained as indicated by shading in Figs. 121 a, b, c, darkest nearer the nucleus. The wall arches finally disappear, with projecting wall piers, and the central pier is deduced to a square. The

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ribs and main arches then spring from the wall at a height above the impost, and only receive their full profiles at some height above their junction with the wall.

This problem of vaulting contains in a nutshell the general course of development in the treatment of piers and imposts from early middle ages to Late Gothic. The undiminished plan of imposts of ribs and of their supports, with little thought for construction of space, corresponds to Romanesque and transition styles, and the simplified combinations, economical of space, to Gothic.

Ribbed Vaults without Longitudinal and Transverse Arches.

If transverse and longitudinal arches be omitted and are replaced by simple ribs, a second mode of simplifying the imposts results (Fig. 122 a, b, c), which likewise influences the sections of piers and also embodies the Gothic, aspiring to lighten the entire structural system. This omission of main arches of the vaults is especially employed when imposts of vault and pier are to be reduced to the smallest dimensions; Ungewitter (p. 126) gives examples of such vaults in the Monastery at Haina; also in hexapartite groin vaults without ribs and with main arches in the hall of the Römer in Frankfurt. This has the advantage that three ribs may be set on a single wall column, and the central pier may be made round or diagonal. Wall arches may then be corbelled out from the impost. Ungewitter (p. 122) gives such an example from the Church at Immenhausen.

Groin Vaults without Ribs.

The greatest possible simplification will result from returning to groin vaults without ribs in Romanesque, permitting only main arches to project below surfaces of vaults; Late Gothic has often done this. The most complex Late Gothic construction of vaults is based on this simple principle.

47. Impost Blocks in Elevation.

The forms of these imposts in elevation may likewise be referred to a few ground Principles; we first distinguish two cases, both wall and main arches being round, or the former are pointed arches of the same or of different radius, than that of the round diagonal arch. In arrangement I of the ground plan, Figs. 121 a, b, c, a polygonal funnel form would occur in both cases at the feet of the ribs and behind them (Fig. 123), which could scarcely be built except in horizontal courses; to make this impost a firm support and to lessen the span of the vault and its thrust, the impost is made a solid block (Fig. 124), against which are set the rib impost blocks, the impost being in sometimes of a single stone, if in accordance with the reduced arrangements II, III, IV, of Fig. 121 a, b, c, ribs and main or wall arches start in combined form (Fig. 125). If wall or main arches and diagonal

arches are round, thus having different radii, then in Figs. 126 and 127 the points b' and b, at which the upper angles b c, b' c' of the arches intersect the corners of the vault above a, will fall at different heights. Joints may then be cut either as at b d or b' d', i.e., the first joint between the ribs and their impost blocks would be too short or too long on their skew-back (Figs. 128, 129) and would have too much or too little bearing; then as indicated by the dotted lines in Figs. 126, 127, the arches must have different depths if the skew-back joints are all to be brought to the same height. In vaults with pointed main and wall arches of the same radius as that of the semicircular ribs, this difficulty disappeared, as well as in vaults where diagonal and side arches were all pointed with equal radii, and lastly in those which combine round or pointed with Tudor or oval arches, as usual in the Netherlands and in England. Finally, to evade the difficulties of the constructions mentioned, the joints of the larger arch are cut horizontal; but this can be done only when the joints do not cut the arch at a too acute angle.

A difference will further arise in the intersection and jointing at the impost between side and diagonal arches, if they do not, as in Fig. 130, meet wall angles or central pier at equal angles, a case usually occurring in oblong groin vaults and in choir vaults. If the cut block becomes too large, one or more horizontal joints are inserted between springing and skew-back joints. The II method of reduction treats the parts as in Figs. 125 to 129; No. III of Fig. 121 is of quite peculiar form in elevation. In both cases, wall and corner piers may extend to the floor or be replaced by corbels, as at b c in Fig. 128, so that the rectangular angle continues to the springing. Yet the diagonal ribs would in No. IV of Fig. 121 only become separate at some height above the skew-backs of wall and main arches, and then intersect each other as segmental arches (Fig. 130).

In arrangement No. IV of Fig. 121, the development of the impost block in elevation is such, that the wall arch starts from angle of the walls as a segmental arch at some height above imposts of the central pier, then intersects it at some height above their penetration in the walls, and finally intersects the diagonal rib at some height above their own intersection. If economy of space is to be consistent with this Principle, and the extreme can be assumed, longitudinal and transverse arches would detach themselves as circular arches at the skew-back above a square pier, wall arches would entirely disappear, and diagonal ribs would strike the angles of the room high above the skew-backs. This would produce a room divided by a square central pier and covered by four regular groin vaults (Fig. 132), appearing as if its walls were afterwards set back to the lines b, c. The

effect would be quite ugly, and in Late Gothic the impost blocks were simplified as much as possible, to obtain the greatest extension of space by a combination of the motives suggested, retaining the central pier in its simplest form, omitting all projections from walls and allowing arches and vault ribs to spring directly from the walls in full semicircular or pointed form, so that only diagonal ribs assumed the segmental form. If the most complex mediaeval imposts be examined, they may mostly be referred to motives I to V of Fig. 121 and their combinations, produced whether ribs approach more nearly the centre of the pier (Fig. 121 c), or they are more distant from it. With rib sections of richer forms in ornamental vaults and those with spiral series, the most complex appearing intersections occur above the impost blocks, but these are always simple in principle and more easily executed than they appear.

The impost block is only to be regarded as a corbel, and may therefore be treated as such; vault ribs and arches may abut against it as segmental arches. This transformation of the impost block into a corbel (Fig. 133) is sometimes used in low rooms, both to allow furniture to be placed against the wall and not interfere with passage up to the height of a man.

In Late Gothic, ribs are frequently set on a corbel below the impost, treated in accordance with the sections of ribs (Fig. 134). If an abacus be added to the corbel, its plan might follow the sections of ribs at the springing. Separate ribs may also receive their required projection by corbelling out above the abacus, if the abacus affords them no support; this is found in the upper dormitory of Abbey at Heiligenkreutz (Fig. 135). (Helfert VI-34-1).

The ribs may also spring from a point (Fig. 136) as common in Late Gothic, and a corbel or capital could then be omitted. If the abacus of the capital or corbel does not follow the profile of the ribs, but all sections of ribs combine in a common polygon at the impost, it is proper to extend the abacus as a prismatic nucleus up to its intersection with the ribs (Fig. 137), an arrangement much favored in the middle ages and especially justifiable, if the central pier also receives the polygonal abacus. Polygonal and also circular abacuses were in use in the late middle ages.

48. Treatment of Impost at Convex Angles.

In arranging ribs and main arches at a projecting angle, differces are possible; it appears most natural that as at the angle of a cloister, the axes of the square on the plan are taken as the centre lines of ribs and main arches (Fig. 138); but main arches then project half their width from surfaces of walls A B, angle A being taken as the intersection of all axes, and a pier with capital or a corbel is required to receive the arch. The pier

may then be a round or a compound pier. If the arches be set back enough for their entire width to strike the angle, their axes are also set back half the width of the arches from the angle A(Fig. 139), so that the Point of intersection A in the interior of the wall is the sPringing point of the axes of the diagonal ribs, in which case the imPost is of regular form, so that the outermost points of the arches form an octagon; the wall arches then entirely disappear, and either a corbel, a compound or round Pier will be required. Or the original angle A may continue to be the point of intersection of the axes of the ribs and wall arches (Fig. 140); the abacus is then of irregular form. If the ribs be now moved so far back as to spring from the main arches and require no separate capitals, (Fig. 141), two capitals or corbels and two piers may be made to project; but complex and ugly impost blocks are Produced by the Peculiar and indistinct intersection of ribs with main arches. If all capitals, corbels, and Piers are to be avoided (Fig. 142), the main arches with their axes remain, as well as the wall arches and their axes A B. But the ribs most properly spring in the direction of the axes A" B" from the angles of the wall and main arches. The wall arches then entirely disappear or intersect the ribs.

To avoid complex junction of the ribs, all the axes might be drawn through the intersection A', treating wall arches as wall niches as in Fig. 139. Ribs, main and wall arches, then with same radius have equal heights of springing, and can be detached by a single corbel at the angle. The arrangement in Fig. 138 may be termed of the earlier, and that in Fig. 142 of the latter middle ages.

All these examples become more complex, 1. according to radii of the arches; 2. according to different heights of different skew-backs with exactly or approximately equal heights of crowns of the arches; 3. according to variety in the sections of the members; 4. according to the lay-out on the plan, and lastly, from combinations of these motives with each other and with addition of late Gothic fancies. In elevation, these imPost forms are treated like those for projecting angles, according to whether on Plan the main arches or the ribs projects more or less from face of the wall.

If the crowns of the vault are brought to equal heights, different heights of springing generally result for ribs and main arches; in early Gothic and in the transition style, for each imPost a separate capital was arranged, but Later Gothic usually avoided Capitals; the uPper bed of imPost block was made the horizontal joint of the abutment, and the block between this and the springing below was divided into one or more horizontal courses of stone.

49. Late Gothic Complications.

Among the sports of Late Gothic, on which are frequently based most pecul

iar forms, is that arrangement of vaults, where instead of springing from a common point in the surface of the wall, the ribs start from three Points, intersecting each other at some height above the springings. (Figs. 144, 148). The oblique view of the interpenetration of the ribs is as in Fig. 144; this is a simple geometrical construction, but really appears complicated, it rich sections of ribs affords opportunity for peculiar interpenetrations of its different members. Similar problems were not too hard for the stone-cutter to execute, and complexity in appearance based on a simple principle directly interested him, and enticed the Late Gothic master into such fancies. An interesting specimen of intersections of ribs above impost is given by Ungewitter (P. 131) from the Catholic Church and the Church of S. Mary at Marburg; another is added from Regensburg in my Beiträge (Taf. 50, Figs. 8-12).

Imposts for Piers set Diagonally.

Another idea of Late Gothic in treating imPosts of vaults is based on piers set diagonally opposite, whose surfaces and angles could be intersected by ribs and sections of the main arches without capitals; if ribs and arches were richly Profiled as well as the piers, very fully developed interpenetrations of sections were formed on the imPost blocks. Intersections of flat surfaces, hollows, rounds, etc., with each other was no rarity in the early middle ages, but only occurred where natural and unavoidable; but Late Gothic sought to produce such interPenetrations of forms to produce original, though not always tasteful effects.

50. Forms of Imposts in Early Middle Ages.

Impost stones were in the early middle ages usually characterized by their form or color; the simplest mode of accenting them was in mixed brick and stone construction, by executing the keystones and imPost stones in cut stone, making remainder of the arches in brick.

In cut stone, simple decorative motives for impost blocks resulted because in many forms of sections of arches in Romanesque it was necessary, either to transform the square abacus into octagonal, not harmonizing with the style at all, or to allow it to project so far, that the angles of the capital had nothing to support (Fig. 145) and became superfluous; the first voussoir was then rectangular in section and assumed its moulded form at some height above the springing, either on a simple inclined plane a b (Fig. 148), or mouldings were returned horizontally at the sides of the arch (Fig. 147), as in the Church at Montreal in France, (about 1200) (V-1-Duc, VIII-439), also in the Church of S. Theodor at Bamberg about 1200 (Beit. Taf. 54-Fig. 1); or any similar transitional form was added at the lower end of the moulding, like that found in the Church at Montreal and in the cloister of the Abbey at Heiligenkreutz near Vienna about 1249 (Fig. 148) (Beit. Taf. 54-

Fig. 8). The best Gothic made the abacus polygonal and allowed the mouldings to spring directly from it; Late Gothic made it similar, or omitted the capital entirely, the section of the arch springing directly from the wall or pier, or was continued down to the base above the floor. Early Gothic sometimes made impost stones ornamental masterpieces, and adorned them by leaves, heads, or even statues. Viollet-le-Duc gives (VIII-442 e. s) a series of such impost blocks from French churches (See IV-149), and Ungewitter (p. 131) cites a similar example from the Stifts Church at Wetter. The motive merely results from an impost stone (Fig. 149) having the plan dimensions e f g h and the height f b, that instead of working out the mouldings alone, foliage ornament or even a figure is cut out of the material to be removed.

51. Profiles of Ribs.

To lighten to the utmost the entire structural system, the Gothic transformed the sections of ribs and main arches of vaults, the angles being replaced by rounds between hollows (Fig. 150 a), or by rounds before a rectangular nucleus (b), later changed into ogees, to indicate their course already in the section. Late Gothic frequently transformed rounds into angular or edged members, or omitted them. But the process of reducing the weight of the mediaeval system of construction proceeded very slowly and gradually and passes through a series of intermediate steps.

Already in the Abbey Church at S. Denis and the Chapter Hall at Vezelay about 1140, we find the earliest transformation of rectangular sections of Romanesque arches and ribs; we find in S. Denis sections of main arches like Fig. 150 a, and of ribs as in Fig. 150 b. The wall arches agree in section with the main arches but are less than half as wide. The forms at Vezelay are softer and more smoothly treated, by smaller rounds combined with hollows, and by ornamental nail-heads, as in Fig. 98, and by refining the mouldings. The sections of wall arches are independent of those of main arches. In the vaults of Notre Dame at Paris, the motive of section of arch in Fig. 150 a is the same for ribs as well as arches; wall arches are like half ribs, which only show the reduced section of main arches.

Shortly after completion of the choir of Notre Dame, soft transitional forms of sections of main arches and of ribs were introduced after 1190 in the choir of the Abbey at Vezelay (Fig. 151), such as occur about 1220 on German monuments. The richer and later Gothic Preferred the roundel, already found in the section of main arches in Fig. 151 b, which assumed the most varied forms (Fig. 152); small rounds and hollows increase in number, the former being almost entirely replaced by the latter, as in Fig. 152 g. Viollet-le-Duc thoroughly considered this Point in VII-503 to 529, of his

Dict. Raiss. de l'Arch. (Ungew. Fig. 99; Beit. Taf. 53, 54.).

Simplification of the system of construction was always joined with enrichment of architectural forms, and we see increasing variation in motives of the vaults, and in the Profiling of ribs and main arches, while the structural system itself becomes more concentrated and more simple.

Forms of Vaults and their Plans.

As a basis of dimensions of sections of ribs is the rule, that like a loaded beam, these must have greater height than width, and must be sufficiently broad to afford sufficient suPport for compartments, executed in brick, or rarely in cut stone; ribs must support on their broad tops and be inflexible horizontally.

Depth of rib is seldom more than twice its width, usually somewhat less, so that a square with an equilateral triangle drawn on its top determines its height and width. Height further dePends on sPan of vault and increases approximately in the ratio of the square of the span, since with the same thickness of masonry of comPartments, weight of compartments increases in proportion to their surface area; approximately, since for the abutting of compartments over ribs and arches a part of their weight is to be deducted. Dimensions of ribs are also based on conditions of resistance of the building material and on the possibility of execution of the ribs. They sometimes have unusually great dimensions, being 1.37 ft. in height and width for spans of 39.4 to 42.6 ft. in the vaults of the Chapter Hall of the Cathedral at Mentz and in the Monastery at Arnsburg (Fig. 153). A series of sections of ribs at same scale as Figs. 151 and 152 is given in Fig. 154 a from tower of Cathedral at Frankfurt, in Fig. 154 b from Cathedral at Wetzler, and in Fig. 154 c and d from cloister of S. Emeran at Regensburg. The last three are not drawn to scale. The rib Fig. 154 b corresponds to the main arch,.

52. Capitals and Bases of SuPports.

All forms of ceiling require suPports to receive the load and to transmit Pressures to earth. Vertical supports are walls, piers and columns; oblique supports for opposing thrusts are buttresses. All architectural styles usually characterize ends of supports receiving loads by capitals, and these transferring pressures to foundations by bases, intermediate members inserting a broad cap or base between the load, suPport, and foundation, as well as indicating its function as a support. Compared with the suPport, the load always aPPears bulky and massive, and an enlargement of the support at its ends is aPPropriate, as it appears pleasing; the load must have a firm bearing and must also be distributed over a greater area at the floor. For round columns, these capitals and bases are generally

transition forms, changing from the round column into the square abacus and plinth, and the capital is always regarded and decorated as a receiving and supporting member, while the base is a member connecting the column and the foundation.

Forms in Early Christian Art.

Early Christian art employed partly columns, taken from Roman buildings, with Ionic, Corinthian and Composite capitals, partly its own columns in imitation of Roman forms. A new form of capital, the byzantine, first employed in the great Aqueduct at Constantinople, and basket-like forms of capitals, were used in Early Christian, with Corinthian-like foliage capitals. When arches were set on columns in Early Christian, the interpolation of a portion of the architrave as an intermediate member or impost block between capital and arch, common in antique architecture, was very soon dropped, and an impost block was used like an inverted frustum of a pyramid, its edges occupied by bands of ornament, and surfaces decorated by foliage ornaments, Christian symbols, etc. This intermediate member had a two-fold purpose; the load found a broader bearing and by the capital could be transmitted to very slender columns; secondly, the insufficient height of columns taken from Roman buildings could be increased in a very simple, though not beautiful way; columns of unequal height could also be equalized.

Impost Blocks above Capitals of Romanesque Columns.

Impost blocks were long retained in the Romanesque style, where required to support massive masonry arches over slender columns; thus in the coupled windows of Romanesque towers and dwarf galleries. These inserted impost stones took the most diverse forms; they were plain pyramidal blocks, as in capitals above granite columns of the double Chapel of S. Pantaleon in Lower Austria, one only consisting of a cylinder decorated by a round-arched frieze (Fig. 155; Helfert, III-14-5); or in windows of towers they are impost stones with two inclined sides and vertical ends, with partly moulded, partly corbelled front and rear faces (Fig. 158).

Antique-like Capitals.

Columns and capitals were directly imported from Italy by Charlemange as well as much later, and their forms were imitated; the Ionic form of capital very quickly disappeared entirely; found latest in the post-Carlovingian buildings at Quedlinburg. But angle volutes reappear in later Romanesque as coiled stems of plants and leaves, and a varied Ionic capital may be seen in some late Romanesque capitals with two entirely separate volutes, recalling forms of capitals in Asia Minor; for such capitals from Regensburg, see Beiträge, Taf. 28, Figs. 1, 2,3,4,9. The earlier Romanesque usually employed forms of capitals, directly imitated from Roman Corinthian and Com-

posite capitals, but also used and preferred impost-block capitals, decorated by interwoven bands and scrolls, foliage ornaments, and fanciful forms of animals.

The abacus of the Roman Corthian capital even continued to exist in early Romanesque as a form with bosses (Fig. 157), and covered by a moulded Romanesque abacus, as on the Cathedral at Spires, and the Church at S. Menoux (V-l-Duc, II-483), where even the astragal is retained; even later, reminiscences of the Corinthian abacus occur on rich capitals with figure sculptures, as on capitals of the Church at Deols (V-l-Duc, II-492), and the porch of the Cathedral at Dijon. The impost-block capital sometimes takes a form differing from the normal one, as for columns of towers (Figs. 158, 159) of the Church at Leiden in Hungary (Helfert, III-14, 13), columns of centre aisle of the Basilica at Rosheim in Alsace (V-l-Duc, II-506), and of the Church at Borzony in Hungary (Helfert, XVI-92, 2) (Fig. 160). Painted impost-block capitals also occur, as in the cryPt of S. Leger at Soissons (V-l-Duc, II-507). The imPost-block capital was exceptionally used in Late Gothic, as in the dwarf galleries of a tower of the Cathedral at Worms (Fig. 161), in a room of the Abbey at Maulbronn (Fig. 162), and on the canopy of a buttress of the Church of S. Veith at Hersfeld. These and the other variant forms correspond rather to wood carving than to stonecutter's work.

Richer Late Romanesque Capitals.

Similar ornamentation is shown by richer Late Romanesque capitals, mostly in the form of the Corinthian bell, sometimes combined with an imPost-block upPer portion, and frequently exhibiting rich foliage decoration, not treated according to nature. About the end of Romanesque and during the transition, the leaves of the bell capital were transformed into shapes like strongly projecting, swelling buds, usually adorned by northern plant forms, and later passing into tufts of leaves, introducing our entire native flora. Corner leaves were usually replaced by forms of birds or dragons, caricatures of men or animals, and the entire capital was sometimes sculPtured. The abacus of the Romanesque caPital usually strongly projects is heavily profiled by rounds and hollows, which frequently exhibit a profile recalling the Doric caPital. Excellent specimens of late Romanesque capitals are found in Viollet-le-Duc. (II-492, et seq.)

Double capitals of small coupled columns of cloisters, dwarf galleries, windows of towers, etc., are sometimes cut from a single stone (Fig. 163), the connecting Piece between the capitals, left to prevent fracture of the stone, also becoming a decoration (V-l-Duc, II-497), as on columns of the triforium of Cathedral at Langres. Among the most beautiful Corinthian fol-

iage capitals of the Romanesque are those of S. Madeleine at Chateaudun (V-l-Duc, II503), and at Vezelay (V-l-Duc, Disc., Pl. 1, Fig. 24).

Decorated Shafts of Columns.

The antique entasis of the column, found in some early Romanesque buildings, later disappeared and was only exceptionally retained in dwarf galleries of choirs, as at Schwarz-Rheindorf, and for small columns dividing coupled windows of towers. Flutes of shafts of piers and columns were also omitted; but they occur as imitations of antique remains in France, as in the vicinity of Autun, also on the Cathedral at Bamberg. Spirally curved flutes like the forms of late Roman columns are imitated in Romanesque buildings, as on the Cathedral at Freising, and in the crypt of the Church of S. Lebuinus at Deventer. The Romanesque style loved to decorate shafts of columns by scale-like patterns or network, recalling fabrics or chain-mail, then by ornamental patterns derived from wood-carving, lastly, by interwoven bands and scrolls combined with forms of animals. Viollet-le-Duc gives a series of such motives. (III-497).

Knotted Coupled Columns.

A peculiar invention of the Romanesque consists in columns found in many German buildings, composed of four or more shafts, tied together in a knot at one-half or one-third their height. Characteristic examples of this are the columns of Jachin and Boaz in the Cathedrals at Würzburg and at Bamberg (Beit. Taf. 25, Figs. 5, 6, 7, 8). Similar knots also occur in the spokes of the wheel window of the Cathedral at Mentz (Beit. Taf. 1, Figs. 1, 2).

Abacuses of Romanesque Capitals.

The abacuses of Romanesque capitals are chiefly moulded, but not decorated. Profiles are usual in the Romanesque, partly like the antique, and composed of rounds, hollows and fillets, but differ from those in Gothic. Decorated abacuses are rarer; Viollet-le-Duc gives some from central France with sunken nail-head moulding (I-1), also Helfert, from Deutsch Altenburg in Hungary, with stepped battlement patterns (Fig. 134). (V-23-9), and I have added two examples with round-arch frieze from Prüll near Regensburg, (Beit. Taf. 39, Figs. 2, 3).

53. Bell Capitals of Transition and Early Gothic Styles.

The bell capital of the transition and early Gothic styles in simplest form consists of a bell-shaped circular mass a (Fig. 135), connected by an astragal b with the shaft or a round pier, projecting as far at top as required by the load supported, and covered by a square abacus, whose corners project beyond the bell half the difference between its side and diagonal. If the abacus be so profiled that the corners of its bottom are inscribedin the top of the bell, this then projects beyond the bottom of the

abacus on its four sides (Fig. 136). But if the abacus circumscribes the top of the bell, its corners then project beyond that. In the first and third cases, the bell will be more heavily loaded by the angles of the abacus than along its four sides, where the bottom of the abacus is tangent to the exterior of the bell; in the second case, the bell will only be loaded by the angles of the abacus, and will not be loaded at four other points.

The next idea was to support these projecting corners of the abacus by leaves, and already in Romanesque it was customary to support them by foliage or figures. The leaves then remained entirely enclosed within the perimeter of the square and projected as far as the abacus itself, but permitted the disk-like edge of the bell to appear between them (Fig. 137). These leaf-buds had already come into use for square projections of piers in the last decade of the 12th century in the Cathderal at Langres; they were replaced by heads on one capital (V-l-Duc, II-498, 499), an idea repeated on the Cathedral at Wetzlar; fully developed bud capitals for round piers and shafts, but without the disk-like bell plate, are first found in the choir of the Abbey at Vezeley (V-l-Duc, II-524) and Notre Dame at Paris (V-l-Duc, II-502); lastly, similar ones with distinctly marked bell and the richest foliage occur in the Church at S. Leu d'Esserent (V-l-Duc, II-504), at end of 12th century.

The leaves generally received a soft outline beneath (Fig. 138 a), which extended to the bud with a stronger movement, as at b. Sometimes in transition capitals, a sunken nail-head band is added to the rib, and another frequently ornaments the lower side of the disk-like bell plate (Fig. 137 left). The leaf-bud motive took the most varied forms, sometimes naturalistic, sometimes freely drawn, sometimes curved sidewise or with side leaves, producing an inexhaustible variety in treatment, imitating the entirely closed, partly open, or fully developed leaf and flower buds (Lat. II, Figs. 14 to 24).

The height of the abacus in transition and Early Gothic is between 1-8 and 1-4 the side of the square. The round abacus instead of the square is rare. The abacus almost always begins with a vertical band (Fig. 138 c, d, e); the riper and later Gothic also treats it with a pointed bowtell (f), a 3-4 round (g), or with a drip (h). Ungewitter (Figs. 358, 359) adds peculiar profiles from Chalons-sur-Marne and Rouen (j). The latter forms are especially suitable for the exterior, to conduct rain water away from the joints.

For larger capitals, the four angle buds in their simple form no longer satisfied the artistically educated eye of the mediaeval master; buds were more richly executed and a second series of leaves was added (Fig. 139),

which again terminated in buds, or in allusion to many Plants with leaves of two shapes, they were treated as developed leaf forms. The double series of leaves were preferable, because they partly covered the blank surface of the bell. (Fig. 170). This surface of the bell could be lessened by reducing the abacus by a cove at its lower edge, not permitting the round top of the bell to project beyond this (Fig. 171). Finally, by adding a specially profiled abacus, it was possible to enlarge the support for the impost of the arch and to give to capital a stronger effect (V-l-Duc, II-504; S. Leu d'Esserent). To animate the capital, it was sometimes covered by concave folds (Fig. 167, right), or to reduce the bell-plate, it was shaped as a pointed quatrefoil, as in the Collegiate Church at Nantes. (Fig. 171, right).

From the basal form of the capital (Figs. 165, 166) naturally resulted a combination, where the abacus and its corners projected less, were placed directly on the leaf-buds and the ends of these were curved inward to conceal the underside of the abacus, as on the rood screen at Friedberg. The projection of the abacus might be further reduced or be suppressed, if its angles were cut off (Fig. 172), as on the capitals of Notre Dame at Paris (V-l-Duc, II-510). The leaves themselves were deeply undercut to the surface of the bell, or if the bell swelled out upwards, as in a capital from S. Blasius at Mühlhausen and in the Church at Frankenberg, the leaves then projected slightly from the bell (Ungew. -196; Taf. 14, Fig. 346).

The top edge of the bell is a simple fillet (Fig. 173 a), with or without a chamfer or cove b, sometimes with a round c, or a richer profile d. The astragal was a half round in the earlier period (Fig. 173 e), a pointed moulding f, with or without a curve g, and sometimes more richly treated and furnished with a drip h, i.

54. Bases of Romanesque Columns.

Bases of columns and Piers in Early Christian and in Romanesque are chiefly the Attic bases, though with proportions different from those in antique bases.

Proportions of Bases of Columns.

Proportions are generally arranged in accordance with building material; the nucleus of the base as well as that of the capital takes into account the direct resistance of the material, and the angles its relative resistance. In both capitals and bases, the material tends to break along dotted lines (Fig. 174). The individual members also alternate in form, so that sometimes merely the general type of Attic base remains.

Other forms of bases recall inverted capitals, but are rare; such are shaped with reference to the Ionic capital on the portal of the Church at Koch-

elten on the frontier of Holland (Fig. 175); those imitated from the Corinthian capital on the Church at Cusset (V-l-Duc, II-138), and on the dwarf galleries of the tower over the western intersection of the Cathedral at Mentz. Bases in the form of an inverted impost-block capital are on the bell tower of Ebreuil (V-l-Duc, II-138). Different forms of bases, allied to the latter, may be regarded as variants of impost-block capitals, and shown by moulded piers of the crypt and dwarf galleries of the Cathedral at Spires; varieties of this kind are represented in Gailhabaud, III, pl. 43, an in Beiträge, Taf. 405 Fig. 9.

Decoration of Torus.

The torus of the base of the column usually remains plain; examples of ornamented toruses on bases of columns are found, decorated by the motive of round-arch frieze, in the Cathedrals at Mentz (Beit. Taf. 39, Fig. 1) and at Geneva (Beit. Taf. 41, Fig. 4), decorated by combats in antique style, on the Portal of the Church of S. Jacob at Remensburg (Beit. Taf. 40, Figs. 3, 7), by a row of leaves, on the Portal of the Church of S. Ulrich at Regensburg (Beit. Taf. 40, Fig. 21), by flowers, on the Abbey Church at Vezelay (V-l-Duc, II-138), and by sculptured animals, at the same place (V-l-Duc, II-138).

Antique architects made the lower torus of the Attic base of semicircular section; mediaeval architecture gave it the shape corresponding to a member leading to the foundation, later period an inclined direction and a semi-elliptical form (Fig. 174). The lower torus usually occupies one-half the height of the entire base. Examples of profiles of Attic bases are given in Viollet-le-Duc, II-132 et seq., and in Beiträge, Taf. 39, Fig. 1; Taf. 40, Fig. 1 etc.; Taf. 41, Figs. 1,7. Profiles of bases recalling true Ionic bases, fluted in the same manner, frequently occur in Berry and Nivernais, according to Viollet-le-Duc (V-l-Duc, II-131, Fig. 9), as in the choir aisle of S. Étienne at Nevers; allied forms are also on columns of Jachin and Boaz in the Cathedral at Würzburg (Beit. Taf. 25, Figs. 5, 8).

Bases with Corner Leaves.

With square plinth beneath the great torus of the base under unequal loading, there was a danger of breaking off its corners, and it did not harmonize with the soft forms of the base. Therefore even in the 12th century, the angles were filled and strengthened by ornaments, by corner leaves, heads, etc. (Fig. 174, right). Beautiful examples of bases with corner leaves of the 12th century from the choir aisle of the Church at Poissy are in Viollet-le-Duc, II-134; from the Cathedral at Langres, II-137; from Notre Dame at Paris, II-144; examples from German buildings, especially from Mentz and Bacharach, are in Beiträge, Taf. 41, Figs. 2, 3, 5. Unfinished bases

with corner leaf remaining as a boss, have been preserved in the Abbey of Arnsburg. (Beit. Taf. 41, Fig. 6).

55. Bases in Early Gothic and Transition Styles.

Avoidance of Corner Leaves.

The simplest way to avoid projecting angles of the plinth was to make its upper part octagonal (Fig. 176), like bases of choir aisle at Chartres (V-l-Duc, II-145), and bases in S. Emeran at Regensburg (Beit. Taf. 40, Fig. 19), or to make the plinth octagonal (Fig. 177), like bases in the Church of Notre Dame at Semur in Auxois (V-l-Duc, II-147). This polygonal form of base was always appropriate where a sharp right angle was exposed to injury and obstructed passage.

Another means of avoiding projecting plinths was by allowing the torus to project far beyond the side surfaces of the plinth, as on the round piers of the Church of Notre Dame at Semur in Auxois (V-l-Duc, II-147), and on bases in the cloister of the Abbey at Heiligenkreutz (Beit. Taf. 41, Fig. 7; Ungew. Figs. 408, 408 a), the angles being reduced by coves (Fig. 178 left); otherwise by replacing the angles by reentrant angles (Fig. 178, right), or the entirely overhanging torus was supported by small corbels (Fig. 179) to ensure it against injury, as in the cloister of the Cathedral at Verdun (V-l-Duc, II-152; Ungew., Figs. 410, 410a). These cuts out of the angles of plinths were also generally retained for polygonal plinths.

Corbel supports of lower torus during Early Gothic were sometimes transformed into very beautiful foliage ornaments, either with a single leaf, as in S. Thomas at Strasburg, or with a cluster of leaves, as at the Cathedral at Regensburg (Ungew. Fig. 410 b; Beit. Taf. 42, Figs. 3, 4, 5. A peculiar example from Gelnhausen, Ungew. Fig. 411). The bases sometimes do not stand on a plinth, but on a pedestal of round or octagonal form, from which result corbelled transition forms, as in the Cathedral at Regensburg (Beit. Taf. 42, Figs. 1, 2). A transformation of such a pedestal into a group of buttresses is found later on a column of the Chapter Hall at Maulbronn (Beit. Taf. 42, Fig. 8).

Omission of Corner Leaves in Perfected Gothic.

Corner leaves went out of use in riper Gothic; they are also wanting in Italian Renaissance, but are exceptionally employed in German Renaissance on the portal of the Rathaus at Freiberg-i-b.

Bases of Double Columns.

Bases of double columns are frequently with their plinths cut from a single block; the part between bases is then retained to avoid fracture and decorated, as in the choir of the Cathedral at Langres (V-l-Duc, II-138).

56. Forms of Piers in Romanesque.

Early Christian Forms of Piers.

As long as men were limited to horizontal wooden deilings or groin vaults without ribs for covering interiors, round columns or square piers sufficed for supports to transmit the load of the ceiling to the ground. If interiors of churches were covered by groin or tunnel vaults with transverse strengthening arches, it was usual in Early Christian architecture to support these transverse arches by strong rectangular projections from the piers, and which projected from the surfaces of the walls of the clearstory. The clearstory walls rested on longitudinal arches, whose supports were likewise rectangular, and which were combined with the former to form piers of cross-form section (Fig. 180).

For wide spans, the transverse arches were required to be very strong, and in order that they might not appear heavy, they were formed in rectangular offsets, to which similar projections of the pier corresponded (Fig. 181). Richly subdivided compound piers were thus produced, around which were carried the profiles of the bases and of the abacus of the capital. Since only half the width of the centre aisle was assigned to the side aisles of vaulted interiors, two square bays of the side aisle corresponding to one square bay of the central aisle, there resulted next the centre aisle a series of coupled arches in pairs, supported by intermediate columns or smaller piers. So far had men proceeded in Early Christian architecture. The Romanesque employed in its earliest period this arrangement of piers unchanged. Arcades of alternating piers and columns with combined arches occurred first at Echternach, as an imitation of Roman arrangement; rectangular enclosures of longitudinal arches first appeared at Hirschau.

In the Church of S. Remy at Rheims, groups of round Piers were employed in the 10th century instead of piers with rectangular projections, indeed with larger and smaller shafts (V-l-Duc, VII-154, 155). Round piers with 4 large and 4 small shafts are then found about 1130 in the Church at Saint-Aubin at Guerande, alternating with round piers (V-l-Duc, VII-157).

Alternating Piers and Columns in Lower Saxony.

A form of pier other than that with cross-form section resulted as follows. The Early Christian basilica with wooden ceiling could generally be furnished with rows of columns to receive longitudinal arches, men not being required to preserve Roman monuments, and robbed them of their columns. No such columns were available in the north, and where men had not advanced far enough in skill to cut stone columns for themselves, they must help themselves as best they could. Otho the Great had sent costly columns from Italy for the Cathedral at Magdeburg, commenced 968, but this was an exception. The expedient was adopted to support the clearstory walls of the nav-

es of churches on alternating masonry piers and round columns, the latter being frequently of wood. This use of alternating piers and columns then long continued after columns were made of stone. Columns could be saved by making piers very large, as common in Thuringia and Saxony; two or three columns could also be set between each two piers, an arrangement also common. Basilicas with alternating round and chamfered square piers occurred in Early Romanesque, as in the Church of Lons-le-Saulnior of the 12th century. (V-l-Duc, VII-158). These piers are square beneath the imPost.

Round Piers with Round Shafts.

This rectangular pier forms a counterpart to the pier of cross-form section. A third arrangement of the pier was much used in Gothic, and likewise occurs already in Romanesque, the round pier with 4 small round shafts, in the Church at Ilbenstadt in Hesse. The round shafts here suPport cushion capitals.

57. Forms of Piers in Transition Style.

From the time that diagonal ribs were introduced and vaults were enclosed by wall arches, the motive for the perfected Romanesque Pier was given (Fig. 182); rectangular or semicircular projections from the pier were introduced for main arches, three-quarter columns for diagonal ribs, and rectangular projections for wall arches. The first semicircular projections from piers are found on the piers of the central aisle of the Abbey at Vezelay at the end of the 9 century (V-l-Duc, VII-159); fluted rectangular projections occur in the Cathedral at Autun about 1140 (V-l-Duc, VII-161).

Since the numerous rectangular projections appear monotonous and unquiet, all principal arches were soon supported by semicircular shafts attached to the pier. In the western part of the Cathedral at Mentz, built middle to end 12th century, this arrangement of the Piers is consistently carried out. All round shafts now received separate capitals, while the abacus and the base also extended around the rectangular portions.

Rectangular Piers in Saxony.

The rectangular pier of the Saxon Provinces, like the square pier, was enriched by rectangular recesses and projections in consequence of the development of the vaults, and not only obtained a more animated section by addition of half columns and three-quarter shafts, but also by replacing the angles by combinations of coves, rounds and fillets (Fig. 183). Rounds then end below the capital in little cushion capitals, but hollows are usually decorated at their ends by ornaments.

Round Columns in Later Middle Ages.

Columns were long retained in Romanesque as intermediate suPports between the piers corresponding to the bays in some Provinces of Germany, but were

later entirely supplanted by piers, and then occurred as tall and slender, or short and stumpy columns or projections of piers, and in dwarf galleries, as well as in ornamental arrangements.

Gothic Round Piers.

But in the earliest French cathedrals, the thick round pier is preferred; continues in use in England, and in some countries using brick for building materials, as in Holland and in northern Bavaria, until the later period of the middle ages. But the round Pier loses all peculiarities borrowed from the Antique, for it has no entasis, and is neither diminished or fluted. In the Early Gothic French cathedrals the round Pier is both used in entire rows, as in the Cathedrals at Paris and Dijon, as well as alternating with compound piers under hexapartite vaults. In Dutch churches with round piers, the piers at the intersection usually take the form of quatrefoil in plan (Fig. 184), while in French churches these generally charge into compound Piers, arranged according to the forms of the imPosts of the arches.

Everything said in reference to the form of Pier, more or less applies to wall and angle piers, in case such exist. Both round and compound piers completely omitted the peculiarities of the antique column and pier, with entasis and fluting, so that they are no longer to be gegarded as individuals with fixed proportions. This certainly is an advance of mediaeval architecture beyond the antique; the mediaeval pier may be adapted to any ratios of magnitudes of the church at pleasure without requiring to change dimensions of the capitals or bases; or conversely, the capital and base may be modified in their proportions according to the purpose to be served and to the masses to which they correspond, without the necessity of changing the dimensions of piers as well.

Round Piers always have round or polygonal capitals and bases; main arches and diagonal ribs, as well as wall-shafts of vaults of the centre aisle then spring from the capitals. In the Cathedral at Chartres, round piers with 4 attached shafts exceptionally alternate with octagonal pèers, whose attached shafts are likewise octagonal. Rectangular shafts attached to round piers occur in the Church at Wolfshagen near Cassell.

Detached and Engaged Shafts. Band Mouldings.

At the Cathedral at Laon (about 1200), the round pier was surrounded by shafts, interrupted at the middle of their height by moulded bands, which served to support both the main arches and the wall-shafts of the centre aisle. The round nucleus of the Pier then received a high capital and a higher base than the round shafts, whose capitals were cut from the same block as the upper half of the main capital (V-l-Duc, VII-165, 166; II-154).

Such grouped capitals with different heights of the separate capitals appear on round piers with engaged round shafts in the Cathedral at Paris (V-1-Duc, II-515), about 1230 in the Cathedral at Auxerre (V-1-Duc, II-513), and about 1240 in the Cathedral at Amiens (V-1-Duc, II-520, 521). In 1230 at the Cathedral at Rheims, the capitals of the pier and of its shafts were first made of equal height, and in case of round piers with 4 shafts (V-1-Duc, II-518; VII-138).

The round pier with round or polygonal detached shafts was so arranged that the nucleus of the pier could be built as small as possible and with a different material. If a very firm, easily worked stone was at hand, like Rhenish graywacke slate, some volcanic stones of the Eifel Mts., or hard sandstone, then round shafts of unusual height might be wrought as monoliths (at Cobern from slate, at Heisterbach from volcanic basaltic lava, at the Cathedral of Bamberg from sandstone). Where such materials were wanting, the shafts were made of pieces bonded to the nucleus by moulded bands (Fig. 185). From the original examples of S. Martin and of the Cathedral at Laon, these arrangements were favorites in Germany from 1200 to 1250 in many cathedrals and monastic buildings, as at Magdeburg, Bamberg, Wetzlar, and Maulbronn.

The through stone courses of the pier, on which were worked the moulded bands of the shafts, covered the lower and supported the upper Pieces of the shafts (Fig. 183); if these were cut from stratified stone, this was set on edge, like wooden posts. It is evidently very difficult to cut all pieces of the shafts so accurately to the same heights, that the through courses of stone with the rings would all be equally loaded. It even resulted from experience with coupled columns, that equal loading of both was not attainable, almost always one of the two being a support, while the other stood as a merely passive piece of decoration. The separate pieces of the detached shafts are then loosely set between joints, may sometimes be taken out (Cloister at Maulbronn), are therefore entirely useless from a constructive Point of view, and have merely a decorative purpose; but they thereby make the thickness of the pier deceptive, and for this reason, the system of engaged shafts was introduced in the Cathedral at Rheims (Fig. 187), where the bond of the masonry alternates in each course, and a through course is sometimes arranged.

According to an old custom, after the last arrangement was introduced, engaged shafts were even characterized as monoliths by Painting, only the nucleus of the pier being ornamented by masonry joints; Ungewitter notes proofs of such painting on piers of the Stifts Church at Wetter and of the Church of S. Elizabeth at Marburg. In both examples, as in the Church last

mentioned, both systems of construction are found in use together. In Rhenish transition style, these shafts are almost always made of black slate, frequently gilded, but mostly left in natural color, or sometimes replaced by columns of other materials painted black.

58. Piers in Severe Gothic Style.

All rectangular projections from the pier were replaced by rounds, and the nucleus of the pier was made square or round (Fig. 186), first in the Cathedral at Rheims between 1230 and 1240. Already in Romanesque, the square pier with its projections had approximated the square set diagonally; in Gothic, the entire plan of the pier may now usually be enclosed within a square set diagonally (Fig. 188).

The motives of forms of piers are then as following:—

1. To the number of ribs and main arches corresponds that of shafts around the Pier, larger ones receiving arches and smaller ones ribs.

2. The abacus of the capitals and the Plinth of the bases are shaPed in accordance with the direction of main arches and ribs.

About 1230, the pier was no longer constructed with the shafts as separate pieces inserted in the nucleus of the Pier, but were worked out of the same piece with this. By the increased number of the shafts, these not only became small, but very small intervals remained between them; the sharp edges separating them from the nucleus were hard to cut, the shafts might spring under their heavy loads, for their slight connection with the nucleus of pier; therefore the sharp reentrant angles were first rounded off (Fig. 188) and later replaced, both for round as well as recessed nucleuses, entirely by hollows (Fig. 189). The piers in the Cathedral at Strasburgh are indeed according to the old, and those in the Cathedral at Freiburg are according to the new method.

The capitals of riper Gothic are exclusively bell capitals with leaf-buds. Further progress in the development of the form of the pier was made by changing intervals between larger and smaller rounds into hollows. (Fig. 189). The plinth of the base and the abacus of the capital were of polygonal form (Fig. 189). The Attic base was compressed and made to project strongly, as best suited the long shafts of the pier. The capitals with buds were replaced by bell capitals with a lightly attached row of leaves.

The late Romanesque and transition styles had first produced a subdivision of the pier in richer form by replacing rectangular projections from the pier by semicircular; Early Gothic did this by rePlacing these by round shafts outside the Pier. If rectangular projections be replaced by round shafts, an arrangement is obtained (Fig. 190), which with shafts of equal size, is emPloyed in the Collegiate Church at Nantes. If longitud-

inal arches composed of 5 and transverse arches of 3 rectangular projections, then by this Principle produces a pier surrounded by 30 round shafts, an arrangement common in the middle ages. Equal diameters of shafts is neither necessary nor desirable. In the first case (Fig. 190), a large shaft for the main arch is replaced by a group of 3 rounds, the middle one corresponding to the wider Part of the arch should be wider than the rounds for the side Portions (Fig. 191).

If a 3-aisled groin vaulted basilica with an intersection (Fig. 192) a and two internally open western towers b b is to have compound piers in a consistent way, then a nave Pier 2 would receive a triple transverse arch next the centre aisle, and a single, or for better construction, a triple one next the side aisle also; the longitudinal arches should be increased on the side next the centre aisle by about the width of a single arch, since they carry the clearstory wall; a simple wall-pier would appear as at 5. But at the piers at the intersections and at the towers, 1, 3, the longitudinal and transverse arches under the towers must be strengthened; they are five-fold, and to them correspond the wall-pier 4 and the corner pier 6 at the transepts. On the principle that heavier arches correspond to greater spans and heavier loading, and strengthened piers to these arches, were arranged the compound piers in several German Gothic cathedrals; each rectangular projection of the piers is replaced by a round.

59. Piers, Capitals and Bases in Later Gothic.

Profiles of arches and ribs, which like piers in Romanesque and early Gothic, were composed of rectangular projections with rounds and hollows, were not only more smoothly treated in later Gothic by transformation of projecting angles into hollows, but were thereby simplified in light and shade to produce a more striking effect. These moulded members forming triply divided arches, earlier constructed of two courses of stones, were in later Gothic combined into a common stronger profile of the arch by hollows.

Change in Form of Abacus.

The square abacus for round Piers corresponded badly to rich forms of imposts, and was therefore soon replaced by the polygonal abacus of richer appearance; but for round piers (Fig. 193) of choir aisles this could neither be regular nor with the Proper number of sides, but only according to the direction of ribs and arches. Hence it was preferred to surround the round pier by small shafts (Fig. 194), each of which bore a separate capital with abacus, and to make this sometimes round, sometimes square or polygonal, the bases corresponding to it as well. For compound piers, the astragal usually extends around the Pier, even across the hollows (Fig. 195); this is true of the abacus. More rarely is the astragal omitted from the nucleus of the

pier, as on the lower side of Fig. 194, only the abacus extending around it, as in several churches in Westphalia. The abacus of the compound pier with hollows usually forms a common abacus, but otherwise extends around the entire outside section of the pier (Fig. 195).

Change in Form of Capitals.

The octagonal and hexagonal abacus is not preferable to the square, because the great projection of the corners may be avoided with the strongly projecting leaf-buds, but also for capitals of shafts attached to piers, they are more easily suited to profiles of ribs and arches (Fig. 196), especially if these are of irregular form. Already in 1230-1240 at the erection of the Cathedral at Rheims, polygonal abacuses of capitals of shafts occur, and in 1240 on the piers of the choir aisle of the Cathedral at Amiens (V-l-Duc, II-518 to 521). Polygonal abacuses with freely projecting leaf-buds are found about 1220 in S. Martin-des-Champs in Paris (V-l-Duc, II-528). These abacuses, arranged in accordance with profiles of the arches, then become regularly star-shaped (Fig. 197), as on the abacus of a capital with 8 doves in the Chapter Hall of the Monastery at Maulbronn. The capitals can only be decorated by leaf-buds arranged at the angles of the abacus (Fig. 198), or at the centres of its sides (Fig. 199); the former occurs in the Church of Notre Dame at Dijon, the latter is in the Cathedral at Strasburg. Round abacuses, as in the Stifts Church at Wetter (Ungew. Fig. 380), like those usually employed on the round mullions of window tracery, are commonly employed in England and are not rare in Dutch churches with round piers. From the large diameter of the pier, the abacus is generally a decagon or dodecagon in Plan. For the round abacus, as well as for rectangular projections from the pier, all transitions from one to the other form disappear, mentioned in Art. 53.

The forms of capitals of later Gothic admitted of many diversities, according to the form and arrangement of the abacus. The bell may remain circular with polygonal abacus, or it may pass into the octagon at top (Fig. 200), as in many Late Gothic capitals. Polygonal piers almost always have polygonal capitals, which may be set diagonally in reference to the piers. The foliage of the capital was already transformed about 1240 into quite naturally treated clusters of leaves in the S. Chapelle in Paris, and these also occur in place of buds, as if separately attached to the bell of the capital (V-l-Duc, II-536). These clusters of leaves and twigs are usually grouped in threes, the uppermost leaf bending its tip downwards, and are often in two rows; magnificent examples from 1230 are in the choir of the Cathedral at Auxerre (V-l-Duc, II-517) and in the Cathedral at Rheims (V-l-Duc, II-518). To review the simpler or more richly adorned capitals of

the best Gothic with their leaves and flowers, fruits, heads, etc., is scarcely possible. Leaves are sometimes bent sidewise, there is often only a pair of leaves on a common stem with flowers and fruits, and they then surround the bell like a garland of loose leaves; a multitude of smaller leaflets is then arranged, and soon merely a few large, much dissected leaves, detailed by leaf-ribs, are applied around the bell. The later Gothic enhances the relief effect of the leaves and makes their geometrical form more prominent.

80. Capitals and Bases in Late Gothic.

Change in Profile.

Moulded members of later Gothic generally experience slight changes, which influence the treatment of the pier. The many small rectangular projections with unquiet effect were replaced by small rounds, which the hollows easily unite. The larger rounds seem too flat at a great height and are therefore made pointed, or bowtells are used instead. Like arches and ribs, piers were then generally changed by richer moulding with small rounds, hollows, bowtells, and fillets, so that they no longer have the effect of mouldings, but as if the entire pier were merely divided into narrow strips. This transformation of the pier first occurs in the Church of S. Urbain at Troyes about 1290 (V-l-Duc, VIII-172); if the profile of the pier is entirelyidentical with that of the imposts, the capital becomes unnecessary, and is merely retained as a reminiscence.

Intermediate are many forms of piers of perfected Gothic, where the thinner shafts supporting thicker bowtells of vault ribs or arches are alone decorated by capitals, as in the Church of S. Katherine at Oppenheim. The Gothic pier of best and of Late Gothic frequently produces the impression, that men first made the plan of the pier rich and smooth, but paid too little attention to effect of light and shade. By too great subdivision of the profile, which extends down to the base, these piers entirely lose clearness and proper effect.

Simplification of Pier.

The nature of Late Gothic is based on a repitition and excess of certain forms of the style, as well as on a simplification of its system. If the pier is to be simplified, already in late Romanesque and in Gothic the shafts below the vault ribs do not extend down to the base, but are formed as short columns standing on corbels, and the ribs are also directly supported by corbels, combined with the capital of the pier, or are arranged directly above this. A very beautiful example of corbelling-out a group of shafts above the capital is given from Semur-in-Auxois (V-l-Duc, II-513, 514).

A second mode of simplifying the pier consisted in so arranging the arches supporting the vault, that their profile at the springing was included within the perimeter of the pier, when this was round, square or polygonal (Fig. 201). Late Gothic is very rich in such simply treated piers, often with very complex imposts. Polygonal piers of Late Gothic sometimes had concave surfaces: these were helically twisted: their edges were replaced by rounds between hollows, etc.

Variations in Late Gothic Imposts.

Variations of late Gothic imposts for simpler and richer forms of piers chiefly follow the following ideas:--1, the ribs, or 2, the arches, or 3, both together, rest on corbels placed above or below the capital of the pier, with or without short columns. 4. The same is true for piers without capitals. 5. The motive changes when applied to hall or basilican designs, and with equal or different heights of imposts. 6. The same occurs in combination with ribs and arches directly springing from the pier. 7. The motive varies in accordance with the arrangement of the vaults in plan and the direction of their ribs, their intersections and crossings.

31. Bases and Plinths in Perfected and Late Gothic.

Like the Romanesque, the Early Gothicalways cut the base and its square plinth from a single block, differing from the Antique, which in large bases always separated the lower torus from the plinth by a joint. But mediaeval architecture generally added a slab or plinth to the base, to raise it and to increase its total width; the plinth was either more or less steeply beveled at top according to its projection, or was connected with the square or polygonal lower part of the base by a cove (Fig. 202). Instead of the bevel or the cove, a new profile was introduced in the Cathedral at Rheims (Fig. 203) to produce a richer treatment of the base; the nucleus of the compound pier properly required a base differing from those of its small shafts; a high base might then be given to it, with which the low bases of the latter could combine, or both nucleus and shafts might have high bases, a mere beveling or cove on the plinth would be too plain to correspond. This justified the insertion of a richer member. To obtain space for seats, to raise the entire base, and to beautify the angles of the plinth, the bases in the Cathedral at Rheims were set on a common polygonal plinth (V-l-Duc, II-146). The late transformations of bases and plinths in Gothic naturally resulted from enrichment of the members of the Piers. The numerous shafts required only low bases; but these could not have the rich profiles, like those of great piers.

Simplification of Profiles of Bases.

In crowding together mouldings the hollow usually disappears, and profile

a (Fig. 203) changes by compression to b, a form already occurring in France about 1280, first found in Germany on a portal of the southern transept of the Cathedral at Mentz, on the Dominican Church in Regensburg about 1272, and about 1300 on the Piers of the nave of the Church at Haina. To low bases correspond low plinths, which could still be cut from the same block with the base. The profile of the upper part of the plinth (Fig. 204 a) united with the base (Fig. 204 b) was simplified (Fig. 204c), and the common polygonal plinth was beveled at top. These innovations were completed between 1325 and 1330 in the choir chapels in Notre Dame at Paris (V-l-Duc, II-180). A second mode of simplifying the base was by omission of first the upper (Fig. 205 a,b), and then the lower torus (Fig. 205 c), replacing these by combination of bevels, fillets, and coves. The upper torus was often removed by weather and frost, as on bases of the ruined Castle of Teutenburg near Vollenhoven in Holland, where the complete profile (Fig. 205 e) may only be distinguished in an entirely protected location, while it has elsewhere even changed into the profile without a round as at f, by rain dropping from the higher stringcourse.

Bases of Ogee Ribs.

If the shafts are changed into bowtells, the base either closely follows the profile of the bowtell (Fig. 206, left) or the lower torus is made circular (Fig. 206, right, like an example in the Cathedral at Regensburg after 1280, Beit. Taf. 40, Fig. 15), so that usually by the insertion of a cove, its upper member passes into the profile of the bowtell. In the oldest form of this plan of base (Fig. 207, left) from S. Nazaire at Carcassonne (V-l-Duc, II-158) (about 1300) the fillet of the bowtell has its own plinth. Another example (Fig. 207, right) (1486) from the Cathedral at Regensburg merely gives a base to the round alone, which dies against the coves of the bowtell (Beit. Taf. 41, Fig. 13). The base may extend around all members (Fig. 206, left) or only around the larger round (Fig. 206, right), ignoring the smaller round and the hollows.

Octagonal Plinths.

If the round base be set on a polygonal plinth, as very common Late Gothic, its surfaces are sometimes concave (Fig. 208), spirally twisted, or decorated by sinking. Beautiful examples of such bases are found in the Church of S. Eusebius at Arneheim. Not only the plinth, but sometimes the lower torus is made octagonal (Fig. 209), and this being composed of eight intersecting rounds, as in the same Church of S. Eusebius at Arnheim.

By combining round and polygonal forms of plinth, with or without concave, or surfaces otherwise decorated, with or without interpenetrations of rounds, plinths set diagonally, with or without mouldings, varied cham-

fers and other transitions of polygons into each other, Late Gothic produces an endless variety of bases, justifiable in smaller and ornamental works. Examples are in Ungewitter, Figs. 417 et seq.; Beiträge, Taf. 40, Figs. 8, 9, also in Kallenbach and Heideloff. Just as simplification of Late Gothic profiles of arches and ribs occurred by suppressing large rounds and be replacing them by hollows and fillets, and overloading the forms was caused by repetition of hollows, the same transformation took place in profiles of bases, of plinths, and of abacuses.

Bases of Varied Heights for richly Late Gothic Piers.

But by multiplication of members of the pier extending down to the bases, these became excessive in number, and it finally became necessary to set the bases at different heights, according to importance of the member of the pier, to avoid the medley of bases, or to omit them entirely. Such an arrangement of bases of different forms and set at different heights according to the importance of the members of the pier, occurs first in the choir chapels of 1325 to 1330 in Notre Dame at Paris; yet this diversity of bases is not yet clearly and distinctly expressed. A prominence of such diversities (Fig. 210) was a favorite in Holland, as in 1369 in the choir of S. Nicolaus at Kampen.

The finest examples are to be found in the great transepts of the Church at Bergen-op-Zoom. Arch mouldings even combine with the window tracery, as in the cloister of the Abbey at Middelburg in Holland, and to the bowtells, rounds, hollows, and fillets, correspond bases set at different heights. A common base moulding then extends around the Polygonal plinths of the rounds and the curved and Plane plinths of the hollows and fillets.

Plinths without Bases.

An example of a richly moulded pier, where instead of members resting on bases, they stop on Pyramidal projections from the plinth, is afforded by a portal of the Church of S. Martin at Landshut. (middle of 15 century) (Beit. Taf. Fig. 12). Another, where the members bend out above the Plinth and so form a common base, is shown by wall-piers of Cathedral at Passau (Beit. Taf. 41, Fig. 11).

82. Capitals in Late Gothic.

The greatly increased activity in building in late middle ages naturally had the result, that men must build quickly, and therefore required skilled and accurate stone-cutters; the number of laborers increased and that of trained architects and sculptors diminished. Technical construction excelled at the cost of art, both in original invention and in subtilities of form. As in treating vaults, Late Gothic is just as inexhaustible in creating original arrangements of piers, capitals and bases, and if

in the Production of masses, the capitals of the Piers were entirely omitted to save time and money, it still created many very beautiful and skilful forms of capitals. Their ornament usually has a conventional character, and is very far from the sound naturalism of Early Gothic, like the ornamentation of Late Gothic in general.

The modeling of the leaves is overwrought, and their contours; the leaf-eyes were enlarged, the movement of lines accented, and the bending of parts or leaves so directly represented, that they usually recall withered plants. The coloring and gilding of the capitals recall hammered work in metal, and evidently produced these excesses. The astragal sometimes disappears and is replaced by the twisted stem of a leaf, and the abacus is also omitted from the capitals of tracery, at Evreux even in 1240 (V-l-Duc, II-533).

The cove of the abacus of the capital is usually decorated by heads, forms of animals, or a row of leaves. If economy be required, all foliage was also omitted, leaving the plain bell of the capital, as in the Cathedrals at Dijon and Narbonne, in the Churches at Colmar and Treysa, and in the churches of the Begging Friars, as in the Church of Minorites at Cologne. Foliage was sometimes painted on these plain bells, as in the Cloister of the Cathedral at Utrecht. As a substitute for the foliage, these simple bell capitals were often richly shaped, peculiar transitions from the round nucleus to the square or octagon were sought, and complicated intersecting forms were employed; Ungewitter gives a series of such cases (Ungew. p 211, 212; Taf. 15).

Renouncing the acquisitions of Gothic, which Italian Gothic could use with small skill, and returning to the Antique, the Five Orders again came into use, and were retained for another great area, whose works often excelled those of Roman architecture, and should be placed beside Greek architecture.

SECTION 4. Buttresses and Flying Buttresses.

33. Buttresses in General.

In every arch the voussoirs tend to force each other outwards, and the lowest voussoir is therefore pressed outwards horizontally by a force, depending on span, form, depth, and loading of the arch or vault. This thrust must be opposed by a heavy mass, whose weight is so great, that it can neither be moved nor be overturned; the arch must be sufficiently strong, that the material may not be crushed by too great stress, resulting from loading and thrust.

For an interior covered by a series of groin vaults, those points of exterior walls at which transverse arches and ribs rest, where the greatest pressures occur, must be strengthened. This may be done by projecting the wall-pier into the interior of the building, thereby reducing the space, or by buttresses projecting externally. Early Christian architecture made these additions for strengthening the walls like slightly projecting pilasters around which the principle cornice was broken, or these ended beneath that and were connected by arches. These pilasters divided the walls in vertical spaces and appeared like vertical members, were adopted by the Romanesque, especially in Germany, and an attempt was made to ornament them and the round-arch frieze by moulding the angles. Their tasteless form was thus avoided in some degree, and was only appropriate for entirely plain exteriors and for building materials admitting of good bond like rubble and brick masonry. Semicircular projections to strengthen walls were frequently employed in French Romanesque churches, as in S. Remy at Rheims. (10 century.) The strongly projecting buttress was generally used as an abutment at the end of the Romanesque and the beginning of the Gothic style. It first occurred in Isle-de-France as an imitation of projections from walls of Roman monuments found there. Internally projecting buttresses were chiefly used in countries using brick work during the later middle ages, the spaces between them being utilized as chapels. After introducing the buttress, walls could be made much thinner, windows made wider, and the entire external architecture be lighter. In Romanesque, walls and projections from piers inside to receive arches and ribs were so massive, that buttresses could be omitted. Among the oldest buttresses in Germany are those of the western tower of the Church at Hochelten on the Dutch frontier (Fig. 211).

The buttress had primarily the function of receiving the thrust of vaults, afterwards that of ensuring the wall against being overthrown by the wind. The line of support, after passing the last radial joint of the arch or the springing joint, takes a direction tangent at the last point of the curve.

Where this intersects a vertical the centre of gravity of the loaded clearstory wall (Fig. 212) of the nave of a church, the thrust S combines with the weight G of clearstory wall in a new resultant taking the direction a b, and which may not fall outside the building, since overthrow, sliding or crushing of the masonry would result. It will then be received by the buttress and transmitted to the ground. Since the line of support may not too closely approach the outer limit of the buttress, to not expose the building material to too great pressure, projecting bases are appropriate. If from c a straight line c d be drawn parallel to a b, such a buttress would suffice to receive the line of support. But if the upper horizontal courses of the buttress are exposed to horizontal sliding, the clearstory walls are scarcely ensured against wind pressure. Mediaeval architecture therefore diminished buttresses upwards by offsets to load the buttress above the application of the thrust and to ensure clearstory walls against bending. Buttresses of 11 century in Isle-de-France, Champagne, and Burgundy, have usually two or three offsets, are sloped at their upper ends and rest on a base with several projecting offsets. Buttresses in Normandy, as on the facade of the Church of S. Etienne at Caen, have no offsets and the base has several offsets projecting only in front (V-l-Duc, IV-282).

Pinnacles of Buttresses.

The weight of clearstory wall and of the pinnacles of buttresses then diminishes the projection of the buttress, or increases the angle a between the line of support within the buttress and a horizontal, according as this weight increases. Gothic therefore introduced pinnacles, or finials, as heavy masses in form of small towers or canopies over statues, supported by columns, or entirely solid, ending in a spire decorated by crockets and cross-flowers.

Upper Terminations of Early French Buttresses.

The elder French buttresses generally terminate beneath the main cornice and either merely strengthen the walls of churches with horizontal ceilings, and are then even perforated by windows, as in the Churches at S. Laurent near Falaise and at Montgaroult and Ecajeul near Mezidor (V-l-Duc, IV-286-287), or strengthen the walls of vaulted churches. They are sometimes directly connected with the main cornice, against which they end vertically, or their upper wash abuts against the Projection of the cornice, as at Montgaroult, or they are connected with the main cornice by small half columns, as on the Church of S. Etienne at Beauvais (12 century; V-l-Duc, IV-288). Buttresses also occur in France with edges moulded by rounds between hollows and a wash is like a shed roof, decorated by patterns like roof tiles (V-l-Duc, IV-289), as at S. Evremont at Creille. On Early Gothic Buildings

in Germany, the main cornice is sometimes broken around the buttress, the upper wash being entirely omitted, as on the Liebfrauen Church at Treves, or this abuts against the Parapet gallery of the roof and thereby ensures this against falling.

Front Offsets of Buttresses.

For normal buttresses in Gothic, the upper shaft is of square section, and the lower projects rather more than the diagonal of the square, the offset of the buttress being Placed at about the height b (Fig. 212). A line drawn through the Point c of the base and Parallel to a b should not be crossed by any other parts, or the line of support would otherwiseapproach too closely to the outside of the buttress, and the building material would be subjected at that point to too great pressure.

Whatever is taken away below b must be replaced by heavier loading of the buttress or by increased projection at the base c, in case its weight is to be retained. If the buttress terminate beneath the Principle cornice, this will of itself determine whether its upper portion is to be long or short; if another member be added above the base, the location of the cap moulding beneath the windows is the best place. This member may be treated as a mere moulding (Fig. 312, right), or may be connected with another offset (Fig. 212, left). For very tall buttresses, one or more intermediate offsets are inserted, whose distances from each other generally vary, and arranged at Points where a horizontal appears desirable; but it offsets in buttresses were avoided, where the architecture was itself subdivided by horizontal members, not allowed to dominate the whole. Buttresses with numerous offsets or with horizontal breaks are found on the S. Chapelle in Paris, on the Church at Vetheuil near Mantes (V-l-Duc, IV-296, 297), and on many towers, as on the Church of S. Elisabeth at Marburg and on the tower of the Cathedral at Freiburg.

Openings in Buttresses.

Fig. 212, right, shows that openings may be made through the buttress outside the line of Pressure of the arch without danger, and if here, an ideal section of a church be assumed with two rows of windows above each other, openings may be made above the base at A, and above the upper and lower cap mouldings at B and C. Such openings were much used in Gothic as Passages, and in connection with continuous galleries.

64. Details of Buttresses.

For the details of buttresses, we shall first examine their wash, offsets, mouldings, then openings through them, and lastly their upper terminations.

Wash at Offsets of Buttresses.

Simple inclined buttresses with a wash of varied inclination at top, as

pecially appropriate for buildings of utility, were seldom used in the middle ages, though found on the Chapter Hall of the Cathedral at Mentz (Fig. 213). Equally rare are buttresses ending in very long and steep slopes without a projecting wash, as on the choir of the Church at Pfaffenheim (Figs. 214, 215; Lubke - 407). Buttresses with very long slopes ending in a wash projecting at both front and sides are found in French Early Gothic buildings, as on the choir chapels of the Cathedral at Le Mans (1220; V-l-Duc,IV-298).

Side Offets of Buttresses.

Side offsets were necessarily much smaller, as on the beautiful buttresses of the Cathedral at Bonn (1321), connected with the oldest flying buttresses in Germany (Beit. TAf. 43, Fig.1.).

Profiles of Offsets, Drips and Corbels.

The mouldings of buttresses are arranged in accordance with the development of the style at that time, and with whether they are broken around the buttress as continuations of the cap mouldings. The water drip of the simplest form is treated as in Fig. 216; example a is from the Deutsches Church at Würzburg, b occurs in the Church at Hirzenach, and c is extensively employed. Late Gothic usually curves the drip as at d. The water drip, supported by separate lower mouldings, occurs on the Church of S. Ulrich at Regensburg as at e (1250; Beit. Taf. 37, Figs. 29, 21).

If cap mouldings are broken around buttresses with large offsets, their wash is usually inclined at an angle of 45, while the wash of the offset of the buttress is steeper as at f; the wash is then sometimes replaced by mouldings, as on the Church of S. Leonhard at Frankfurt-a-M, at 1 (Beit. Taf. 43, Fig. 11). A second example from the same church (Beit. Taf. 27, Fig. 2), in order to permit passage, shows the foot of the buttress limited and the moulding supported by corbels. Examples of limitation of buttresses are found on the Cathedral at Regensburg (Beit. Taf. 27, Fig. 3), to afford light to windows of choir chapels. Buttresses projected from the wall only at a considerable height above the floor, to permit passage, as on the Cathedrals at Maissen and at Passau, where they indeed lost their purpose and were merely retained for consistency; they were then supported by flying buttresses abutting against the adjoining building, as on the choir of the Monastery at Lichtenthal near Baden (Fig. 217).

The cap moulding was sometimes broken upwards on the face of the buttress to receive and enclose a tablet for sculpture, as on the Cathedral at Geneva (Beit. Taf. 43, Fig. 9), and on the Church of S. Lorenz at Nuremberg (Beit. Taf. 43F. 10). Variations of offsets of buttresses are shown in

Figs. 218, 219. More complex forms occur on the Cathedral at Laon (Fig. 220). Late Gothic loved to enrich offsets of buttresses by parts set diagonally (Fig. 221), and the best period liked to load them with the ornamental features developed in the treatment of pinnacles.

Passages through Buttresses.

Passages at the height of the base are employed in the finest way on the Cathedral at Regensburg. Openings at the level of the cap moulding are sometimes arranged so that the passage is treated as merely provisional; then corbels are built in (Fig. 222), on which beams may be laid during necessary repairs, as on the choir of the Church of S. Burkhard at Wurzburg (Beit. Taf. 59, Figs. 1, 2), or the buttresses are connected by a wall up to the cap moulding (Fig. 223), on which may be laid planks, as on the choir of the Church of Capuchins at Wiener-Neustadt. Yet passages are usually produced by dropping back the wall (Fig. 224), as on the Church of S. Elisabeth at Marburg.

Upper Ends of Buttresses.

As for upper ends of buttresses, the simplest form is the shed roof, where according to the slope, beds of the stones are horizontal (Figs. 226, 227) or are perpendicular to the slope (Fig. 225). For a slightly inclined wash, the jointing may be so arranged that its surface consists of a stone slab (Fig. 228), construction not to be recommended, on account of the penetration of water into the joints.

To project the side surfaces of the buttress, the moulding of the drip may likewise extend along the sides of the wash (Fig. 229). The drip may also extend horizontally around the buttress (Fig. 230), so that the moulding on the ends of the wash dies on the horizontal moulding. The combination of this with earlier arrangements retains this form at angles and omits the horizontal moulding at the sides of the buttress (Fig. 231). Horizontal and inclined mouldings may have different profiles, so that the former may serve as a corbelling for the latter (Fig. 232).

The other mode of covering the buttress, most used in the middle ages, is by a gable. (Fig. 233). Very old examples are found on the Cloister at Maulbronn about 1230 (Beit. Taf. 43, Fig. 2), and on the Church at Ebrach near Bamberg. The acute angle of this gable was usually replaced by a round in the earlier period, or in examples from Maulbronn and Ebrach by a Fleur-de-lis section (Fig. 234), whose width corresponds to that of the prismatic stone block.

If the shed roof be combined with the gable, a favorite form in Gothic is produced (Figs. 235,236), where shed and gable may have the same or different inclinations and corresponding heights; if their washes are moulded,

peculiar acute intersections (Fig. 237) of the mouldings result, executed in stone with difficulty and also look ugly. These may be avoided if the stone joints below the wash are transferred upwards from a to b; but the wash with its cut-off angles would then look badly. The interval a b is then generally utilized in Early Gothic for a corner leaf-bud (Fig. 239) or some othe sculpture, or a crocket in Late Gothic, against which the mouldings stop; by returning the moulding around it, the corner is also changed into a corbel against which the mouldings abut (Fig. 240, left); these corbels may then be treated as a continuous molding, sometimes identical with that of the gable or shed roof, sometimes not so (Fig. 240, right).

The upper surface of the gable or shed roof is generally plain in German work, but in French is covered by a scale pattern, imitated from roof slates or tiles (Fig. 241), and in English buildings it is stepped with several drops (Fig. 242). Viollet-le-Duc gives a collection of such scale patterns (V-100 et seq). A connection of upper parts of two buttresses by an arch for supporting a tower is found in the Church of the Capuchins at Wiener-Neustadt.

Connection of Pinnacles with Gutter and Main Cornice.

An important part is played by pinnacles, if they are connected with gutters and outlet openings of the main cornice. The discharge channel is most simply connected with the buttress by a corbel, as on the Church of S. Katharine at Oppenheim (Beit. Taf. 43, Fig. 5), or this channel is supported above the wash on the buttress by a short pier, wider or narrower than the channel itself, as on the Church at Wetter. If the spout be very long for a strongly projecting buttress, it is also supported by a small separate column set on the gablet of the buttress; thus at the Church of S. Stefan and the destroyed Liebfrauen Church at Mentz (Ungew. Taf. 28, Fig. 660 a) and on the Church at Oestrich in Rheingau (Beit. Taf. 43, Fig. 7). This column is also replaced by a pinnacle, through which the channel passes to lead the water to a special gargoyle, as on S. Benigne at Dijon (Ungew. Taf. 28, Fig. 660 b). On Early Gothic churches, the main cornice frequently extends around the buttress and forms a basin, which collects the water and discharges it through a spout, as on the Liebfrauen Church at Treves and on the Church of S. Elisabeth at Marburg. The basin is sometimes divided, and the water being discharged through two gargoyles set diagonally, as on the S. Chapelle in Paris.

85. Pinnacles, General.

As loading masses, pinnacles occur early in the middle ages with the same purpose as loads at the ends of pediments in all earlier architecturel periods; among the oldest known are those of the Collegiate Church at Poissy

(V-l-Duc, VII-177) (beg. of 12 century); also a very old example on the towers of choir of Cathedral at Würzburg. The motive of the pinnacle is always the tower, rising above an open or closed structure and it is developed more or less as a tower; thus on the Hall of the Synod at Sens (V-l-Duc, VII-8184, Fig. 7 b; 1250), and the transept gable turrets on Cathedral at Meissen (1266-1293; Beit. Taf. 45, Figs. 1,2). As loading abutments of the flying buttress, the pinnacles play a part still more important, than that of loading the buttress.

The simplest form of pinnacle is always a square or polygonal portion, called the body in the middle ages, ending below with a horizontal cornice with or without gablets, and crowned by a slender spire, termed the final in the middle ages. The body is always either a solid nucleus, plain or is decorated by blind windows, or is perforated, so that the angles become the supports of a canopy into which the upper parts of the open windows are transformed.

The horizontal cornice is treated like a main cornice at reduced scale, and is sometimes adorned by battlements, like the examples from Meissen and Sens. Gablets are imitated from gables of towers with their window openings, and spires are like those of towers. Gablets and final are crowned by buds with longer or shorter stalks, as in an example from Meissen.

For the ratios of height of final and of its subdivisions, definite rules cannot be given, as these depend on individual cases. The required loading generally fixes the height, and the ratio of the spire to the body first depends on the requirement, that the wind must not overthrow the pinnacle under the most unfavorable conditions.

If the ratio of weights of body of pinnacle and of its spire be computed, the weight of spire is to that of the body as 1 : 3, for equal areas of base and heights, or the volume of a pyramid to that of a prism having equal sides and altitudes. If the spire must have the same weight as the body, then must its altitude be three times that of the body.

Thus heavy pinnacles require a tall body, since its weight is but little increased by an increased height of spire; light pinnacles serving for ornament, may have relatively tall spires. For conditions of stability of pinnacle against wind pressure, its loading first comes into consideration. The pinnacle will be more stable, the lower its centre of gravity, but the lower the pinnacle, the greater must be its weight and area of base. Wind pressure may usually be resisted by cramps and joggles and may be neglected.

Construction of Pinnacles.

Proportions of details of the pinnacle partly result from its magnitude

and partly from the heights of courses of stone. If we assume a = 1.64 ft. (Fig. 243), making the spire h' = 7 a and the body = 5 a, for courses of stone 1.64 ft. high, we have 8.20 ft. height of body and 11.47 ft. height of spire, with 5 courses in body and 7 in spire. But the upper part of the pinnacle with the cross-flower are usually cut from a single block; therefore 10 courses of stone at most will form the entire height of the pinnacle up to the cross-flower, and this with necking and knot are set instead of the two upper courses.

The top course will end in a point, which could not be cut and would look bad; therefore a certain top width is always assigned to a spire, either terminating in a horizontal plane or the spire ends in a blunt pyramid (Fig. 244); whose junction may be at the height a b. An absolute law in architecture requires the crowning of all free-ending architectural members; the projection of the free-ending crown is fixed by the width of the body of pinnacle. Early Gothic permitted the pinnacle to end with a flower, not wider than the topmost stone brick, and whose height with or without necking and knot was fixed by two equilateral triangles, or better by two squares on account of perspective fore-shortening, inscribed in the outline of the stone block.

For smaller finials, the entire spire and body of the pinnacle, or each part separately, was cut from a block of stone; the projection of the cross-flower was then arranged according to the dimensions of the block. Proportions frequently vary; thus for the pinnacles of the S. Chapelle at Paris, the height of the body of the pinnacle equals its width a, that of the spire is 4 a, making the total height with cross-flower 5 a, that of the cross-flower alone being a. For the pinnacles of the Church at Friedberg, h' is 5 a, or 4 a without cross-flower and necking.

The angles of the pyramid were already in early Gothic ornamented by angle-flowers or crockets, whose projection was again fixed by the blocks from which the separate stones of the pyramid were cut (Fig. 245, plan); to each course of stone corresponds a crocket, and therefore the steeper the pyramid, the less the crockets project, or the less steep, the more they project. Gablets at base of pyramid were first made equilateral, or with base equal to altitude; later, they were usually higher, about the diagonal of square of the base. They were likewise crowned by crockets, cross-flowers or knobs, and their total width fixed the projection of the cross-flower or spire. If the pinnacle be narrower than the height of the course of stone, and if b b is the joint between spire and body, a lower point is taken as the lower end of the pyramid (Fig. 246), so that b b equals or is less than b c. The gablet then projects about 1-6 of the width a. The height of the gab-

let with cross-flower and knob will then equal twice the height of the equilateral triangle with side a, or is equal to diagonal of square described on a; all these dimensions of pinnacles possess only relative value, like the theories of Rorizer and Lacher, preserved from the middle ages.

Rules by Rorizer and Lacher.

The "Little Book of the True Pinnacle" by Rorizer, Cathedral architect at Regensburg, is printed with Reichensperger's minor writings, and gives the following rules. If a b be the width of base of pinnacle, then dimensions of all details of pinnacle are given by the quadrature (Fig. 247), when within the square on a b is inscribed the diagonal square c d, and within this again a square with a side 1/2 a b, in this a square with side 1/2 c d, etc. In the plan (Fig. 248), c d is the width of the body of the pinnacle , 1-2 a b is that of the panel of blind tracery. The prolongation of the side 1-2 a b to the line c d fixes the total width of the band c e, and the prolongation of the side 1-2 c d gives the width e f of the cove. The diagonal e e of the corner band gives the width, and the basal square a b gives the projection of the crockets of the spire, as well as those of the base and of the gablet.

The height of the pinnacle including the base is 8 a b, and that of the spire is 7 a b. The width e f of the cove of the blind tracery is taken on the width of the top end of the spire, and the height of the gablet is a b. The gablet moulding is drawn parallel to its sides, and the width of this again equals the breadth of the band c e. By extending the inner lines of the gablet, the points h i are found on the lower width of the gablet finial; this has the same height as the gablet, and the dimensions of its knob are fixed by the width c e of the angle band of the pinnacle. The height of the crockets equal their width, the lowest commences the spire and receives the gablet moulding. The width of the cross-flower of the spire (Fig. 250) is a b, its height with stem is 2 a b, without stem 1/2 c d. Its knot rises about c e + e f above the upper end of the stem, and like the neck moulding, its height is 2/3 the height of the cross-flower. The total width of the knot is 1/2 a b and that of the neck moulding is c d. Six crockets are spaced between necking and base of spire.

In Lacher's "Instruction", likewise printed in Reichensperger's minor writings, 8 a each for body and spire of the pinnacle are termed "new proportions", and 7 a being also recommended for body and 8 a b for spire. All rules by Rorizer and Lacher are only suitable for small purely ornamental works of Later Gothic, and must first agree with the quality of stone. The basis of the rules of Rorizer and Lacher is evident, if we remember that all dimensions are so fixed, that spire as well as body of the pin-

nacle can be cut from a single stone, that account be taken of fore-shortening and diagonal setting of the pinnacle, and that esthetic effect be never forgotten. (Crockets and cross-flowers, Taf. 1, Figs. 1 to 13). Early Gothic generally gave the cross-flower less width than the body of the pinnacle.

66. Details of Pinnacles.

For further details of treatment of pinnacles, stems and knobs of cross-flowers and those of gablets are generally of octagonal shape, and the upper part of spire beneath neck moulding and above the last crocket is likewise octagonal (Fig. 250), or the entire angle of the spire is chamfered, so that the crockets are not attached to a sharp angle, but to a plane. A horizontal moulding is sometimes placed between body and spire, so that the gablets rest on it.

Angles are very rarely without crockets, and this is only justifiable for very small pinnacles (S. Urbain at Troyes, 1290). Crockets are generally spaced according to number of courses of stone, and are more numerous and set closer in Early, than in Later Gothic. Distance of topmost crocket from neck moulding usually equals the distances between other crockets, but is rarely greater. A separate band is sometimes arranged along the angles of the spires of towers, as on many French churches; then the surface of the spire of the pinnacle is decorated by scale patterns or blind tracery; these angle bands are then sometimes rounds terminating beneath the neck moulding, giving oppurtunity to make this of quatrefoil form.

The first wxamples are afforde by the great Cathedrals at Rheims, which also show an octagonal spire surrounded by four smaller spires. Octagonal pinnacles are rare; regular or irregular hexzgonal pinnacles (Fig. 251) are also rarely employed, as on the Cathedral at Frankfurt-a-M. Everything said of details of pinnacles also applies to richer buttress gablets with crockets and cross-flowers.

The surfaces of the body of the pinnacle are chiefly decorated by blind tracery, which in richer forms those of large dimensions exhibits all the characteristics, of window tracery; angles then usually have small columns (Fig. 252) with separate capitals and bases, which frequently support smaller angle pinnacles, these treated in accordance with rules already given, and sometimes connected by tracery balustrades, as on the choir of Notre Dame at Paris (1308). If buttresses are ornamented by open structures like pinnacles, or pinnacles are treated like canopies over statues, the canopies have vaults of any form derived from groin or star vault.

Reduction of Weight of Pinnacle.

The pinnacle is usually made lighter in the late middle ages by hollow-

ing out both the body (Fig. 253, left) and spire of the pinnacle, or like the pinnacles of the choir of the Cathedral at Regensburg, by partial perforation of the blind tracery panel (Fig. 253, right; Beit.Taf. 45, Figs. 3, 4). The late middle ages also curved the forms of gablets and of spire of the pinnacle, a treatment depending on the development of the gable. Curved buttress gablets are found on the choir at Ebrach (about 1240).

Connection of Pinnacle with Buttress and Main Cornice.

We here briefly consider the connection of the pinnacle with the buttress. If the pinnacle has the same thickness as the buttress, it then rests directly on its wash with or without a base, or if this be at the height of the main cornice, which is broken around it, the pinnacle forms the proper continuation of the buttress. If the main cornice is connected with arcade balustrades, the body of the pinnacle then has at least the height of the balustrade, whose endings are worked on it (Fig. 254 a), or separate panels are inserted between the pinnacles (Fig. 254 b). The pinnacle sometimes stands outside the balustrade (Fig. 254 c); in all three cases the horizontal mouldings of the balustrade stop against the body of the pinnacle or are broken around it. The height of the body of the pinnacle above the balustrade equals the side or diagonal of the basal square, or sometimes the upper edge of the balustrade is taken as the bottom line of the blind arches decorating the body of the pinnacle. If pinnacles occur in combination with gablets, as on portals, spires of towers, and purely ornamental works, its height must be made to accord with the height of the gablet. Then for structural or esthetic reasons, this will be made higher, lower, or of the same height as the gablet.

The offsets of the buttress are usually decorated by pinnacles, sometimes set parallel, sometimes diagonally. Especially for richer angle buttresses of Gothic towers (Fig. 255), these developments of pinnacles are treated in combination with freely aspiring canopies, ornamental gargoyles, corbels for statues, sometimes with perforated, sometimes with solid bodies of pinnacles, forming masterpieces of stone-cutting, and such pinnacles are even developed in centralized arrangement as detached works, such as fountains, memorial pillars, pyxes, etc.

37. Flying Buttress.

For churches with side aisles, as in basilicas with one or more aisles, the line of support of vault of centre aisle must either remain within the pier supporting the clearstory wall, which therefore requires strengthening next the side aisles, or a flying buttress must be arranged at the point a (Fig. 252), at which the line of pressure cuts a vertical through the centre of gravity of clearstory wall, to oppose the thrust of the vault

of the centre aisle at the point a another thrust, thereby forcing the main line of support towards the axsis of the pier. This flying buttress is frequently concealed beneath the roof (Fig. 253, left), but usually appears above it as a free architectural member treated with all Gothic characteristics, serves for structural purposes, and also to conduct rain water away from the roof of the middle aisle. The arch almost always supports an inclined strut, which supports the portion of the wall above the springing of the vault and is generally finished as a channel for water. Only exceptionally, as on the Church of S. Jacob at Rothenburg, are these arches arranged without inclined struts; the flying buttress thensprings from the clearstory wall like a great ray and descends as a powerful arch down upon offset of the buttress.

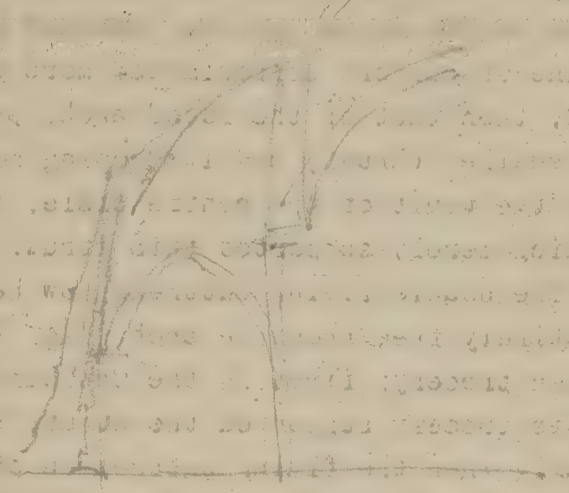
Earliest Flying Buttresses in France and Germany.

The oldest flying buttresses on the exteriors of buildings are those of S. Remy at Rheims, (second half of the 12 century) (V-l-Duc, I-62), and the oldest in Germany are those of the Cathedral at Bonn (about 1221). These correspond to the location at which the thrust made itself felt. The line of pressure of the vault leaves the clearstory wall at a mathematical point (Fig. a 257), and it tends to push outwards the entire part a b of the clearstory wall up to the mid-height of the vault or if the weight of the roof be too great, to bend it outwards.

Flying Buttresses of French Cathedrals.

If a wooden timber be placed against the wall from a to b and this be stayed against a solid abutment by two wooden struts, the thrust between a and b would be completely resisted. Translated into stone construction, this problem would be solved as in the choir of the Cathedral at Soissons in the beginning of the 13 century, where a pilaster projects from the wall and two flying buttresses abut against this, their other resting on a massive buttress (Fig. 257; V-l-Duc, I-62). The flying buttress then resists the thrust of the vault by the weight of its voussoirs, its coping loads it, conducts away water, and forms a direct strut against the clearstory wall. The skew-back against which the flying buttress rests, was in Early Gothic supported by small columns, as in an example from Soissons. On the Cathedral at Amiens with the same arrangement, the coping of the upper flying buttress is formed as a water channel, and the same flying buttress is decorated by crockets.

In exceptional cases, as on the Cathedral at Chartres with unusually thick vaults (1.30 ft.) and heavy proportions, two flying buttresses are connected by radially set columns (Fig. 257, right), the upper flying buttress merely serving to load the lower one (V-l-Duc, I-65). The tendency of Goth



ic to lessen weight in its entire system as much as possible led to making the flying buttress as light as possible; this was first done by not making it a round arch but pointed. This lessened the load on the pier of the middle aisle and also secured greater stability of the arch, since the line of support approximated more closely to the middle line of the pointed, than that of the round arch, and for equal spans the pointed arch had a smaller thrust, and its coping more strongly opposed as a strut the thrust of the vault of the centre aisle, than the pressure of the arch itself, which merely supported this strut.

The double flying buttress now became indispensable to make this strut entirely free from the arch (Fig. 258, left), and they were connected by open tracery; first in the Cathedral at Amiens about 1260 (V-l-Duc, I-72). This tracery supported the strut, but did not suffice as a loading, especially when the flying buttresses of the choir had to oppose not only the thrust of single, but of two ribs, besides that of the main arches, to neutralize this thrust; therefore a strut was placed above the arch and strongly connected with it, sufficient for the requirements, and by open tracery supporting a second lighter strut, especially serving as a water channel (Fig. 258, right), as on the choir of the Church at Eu and on the Cathedral at Troyes, from 15 century (V-l-Duc, I-73, 77).

As building materials employed very hard stones, basalt, granite, and hard limestone, so that struts and flying buttresses could be made of the smallest dimensions (V-l-Duc, I-75,73; examples from Clermont Ferrand, Narbonne, and from S. Urbain at Troyes).

88. Detail Forms of Flying Buttresses.

Connection with Clearstory Walls.

As to details of forms of the flying buttress, since the thrust of the vaults of the centre aisle enters the flying buttress at a (Fig. 259), the portion between it and the strut may be perforated, as by cusped quatrefoils on the Cathedrals at Freiburg and Strasburg.

External and Internal Passages.

Since wall piers supporting the vaults and clearstory walls could be partially relieved of their loads, an opening could be made through the pier itself below the point a (Fig. 260), providing an internal passage around the church; this was rarely placed above the springing of the compartment of the vault (Fig. 261), as in the Church at Harderwyck in Holland. The flying buttress further rested directly against the clearstory wall or against a pilaster, interrupted by a small column in early Gothic, as on the Cathedral at Feiburg (Ungew. Taf. 35, Fig. 728). Between this column and the wall then was naturally an external passage around the church (Fig. 262),

if the clearstory wall was set flush inside, as in many German and French buildings. With internal passages, these occur on the outside (Fig. 262), then omitted when the width of the window is considerably less than the clear width between buttresses, and then spanned by simple arches, as on the Church of S. Ulrich at Regensburg (Fig. 263).

For churches whose windows occupy nearly the entire width between the buttresses, the clearstory walls may be reduced to their least thickness by introducing clearstory windows, and their thickness at top required for gutter and principal cornice will then be obtained by corbelling (Fig. 264), as on many churches in Holland.

Channel for Water.

As for removal of water by flying buttresses, these sometimes support at their upper ends short hollow columns as pipes, through which the water runs from the gutter of main cornice to the channel of the flying buttress. These pipes sometimes end in gargoyles, as on the Cathedrals at Amiens and at Strasburg (V-l-Duc, VI-24). The channel in the coping of the flying buttress is open, rarely a closed tube, as on the Cathedral at Feiburg (Fig. 265). The latter is not advisable because easily clogged. Instead of hollow columns to conduct water to the channels, open channels are preferable, as on the Cathedral at Regensburg, a separate grooved piece is inserted between the gutter and the channel of the flying buttress, as on the Cathedral at Auxerre (Ungew. Taf. 26, Fig. 735; V-l-Duc, IV-155).

Channels of flying buttresses extend through the buttresses of the side aisles and end in gargoyles, or end at the back of the buttress in two pipes at right angles, and the water passes through these into the gutters of the side aisles, as on the Cathedral at Regensburg. The latter also retains crockets even with channels, if they are divided or perforated at their bases, as on the Cathedral at Cologne. In French buildings channels are mostly without crockets. Sections of flying buttresses are rectangular or sometimes richly moulded on the lower side (Fig. 266), as at Oppenheim and Cologne, and on tower of Cathedral at Frankfurt-a-M (Fig. 267); on the Church of S. Eusebius at Arnheim, the backs of the choir struts are of curved form (Fig. 268), and also the flying buttresses of the nave of the same church (Fig. 269), and the flying buttresses of the choir of the Church of S. Nicolas at Kampen are strengthened on backs and sides by mouldings (Fig. 270).

A Projection at Top of Flying buttress.

The block against which the flying buttress abuts in the earlier period while still a quadrant, ended in a vertical joint (Fig. 271), or in an oblique joint for a pointed arch (Fig. 272); the moulding of the sides of

the flying buttress stops against this (Fig. 271) or returns vertically downwards (Fig. 272), as on the Church of S. Katharine at Oppenheim and the Cathedral at Cologne. These abutment blocks were sometimes in form of special canopies, as on the Cathedrals at Cologne and at Beauvais (V-l-Duc, IV-184). Wall buttresses against which flying buttresses abut (or if these are wanting, the projections of the flying buttresses against the clearstory walls) were usually loaded by small buttresses, around which the main cornice was broken, and ended in pinnacles between balustrades.

Projection at Base of Flying Buttress.

The buttress projections of side aisles, against which abut flying buttresses, are heavy masses, against which the main cornice abuts or is broken around; a passage is usually formed through their lower ends, and they terminate at top in a shed-roof form, or have several offsets with gablets or wash, with or without ornamental accesories,like the treatment of the buttress and of the pinnacle canopy. In older French cathedrals, the coping moulding of the flying buttress sometimes extends over the buttress and ends in a cross-flower, or gargoyle, if it has a channel, as on the upper part of the Cathedral at S. Denis, built under St. Louis (V-l-Duc, I-33).

The heavier these buttress projections, the more in accordance with the parallellogram of forces would the thrust of the flying buttress, which combined at a (Fig. 273) with its weight to form a resultant, be forced towards the interior of the buttress, so that the projection of the abutment would be lessened. This projection would be further reduced, if as in Fig. 274, the centre of gravity of the abutment were moved back by moving the pinnacle towards the vertical axis of the vault, as well as the intersection a of the line of support of the flying buttress with the vertical axis through the centre of gravity of the buttress; if A B C D E be the buttress, the line of support would intersect its vertical gravity axis at a and would continue to t; but if the buttress be loaded by the mass D E F G, the line of support intersects at a' the common vertical gravity axis of the buttress and pinnacle, and the line of support continues from a' in a more nearly vertical direction a' b'.

But the projection of the buttress would be least if the loading mass were in part permitted to rest on the foot of the flying buttress itself, since the common centre of gravity of the buttress would most closely approach the vertical axis of the vault; this first occurred on the Church of Notre Dame at Dijon (V-l-Duc, IV-139). The loading mass might then be moved so far towards the vertical axis of the vault, that the common centre of gravity of the buttress would lie over the foot of the flying buttress (Fig. 275). The common centre of gravity a' cannot more nearly approach the axis of the vault, that the resultant of the thrust and verti

oal pressure may not fall too close to the intrados of the flying buttress.

Removal of Water drom Roof of Side Aisle.

The offsets of these loading masses may occur above openings for water. The bottom of this opening usually either forms the highest point of the roof gutter, the water being conducted beside and around the buttress to a gargoyle projecting therefrom, or conversely, the lowest point of the opening forms the lowest point of the gutter, from which water flows through the centre of the buttress to a spout. A third mode of removing water is by gargoyles set in the angles between the walls of the side aisle and the buttress.

The design of the roof of the side aisle likewise influences the form of the offsets of the buttress and that of the gargoyle. Instead of making these of shed roofs, they may be hip roofs, either be arranged as on many Dutch churches, so that the ridges coincides with the division into bays, (Fig. 276), when the windows of the clearstory may have any desired height, extending down nearly to the gutter, the water being then discharged through a spout at the middle of each bay. Or the hip roofs may come over the bays (Fig. 277) the water passing direct to the buttresses in channels of slight inclination, the windows being intersected by the roofs at bottom, or they are also hipped on the inner end on the line a b (Fig. 278), sufficient light entering the window, or the window may commence above the roof only.

Forms of Abutments.

According with their function as loading, the offsets of the buttress are generally wider than the flying buttress, so that the flying buttress (Fig. 279) finds room behind this for itself and for the entire width of its coping. If as in some Dutch churches, a row of narrow chapels extends around side aisles and choir, the backs of the buttress offsets are made stronger and heavier by wings forming a cross-shaped plan (Figs. 280, 281), as on the Church at Coess. If a pinnacle or group of pinnacles load the buttress offset properly, it must be moved back as far as possible towards the axis of the vault and be massively constructed; if it be considered a decoration, this need not be done, as on the Cathedral at Strasburg; if the pinnacles are treated as not very heavy masses, the gain or loss will not be large; pinnacles are usually set merely on the middle of the buttress, as on the Cathedral at Chalons, but their position is determined more by decorative than by structural reasons.

A strengthening of offsets of the buttress by wings set obliquely frequently occurs if choir chapels are inserted between the main buttresses of the choir, so that the wings serve as extensions of the walls of the

chapels (Fig. 282, plan), as at Cologne and Amiens. With several side aisles double flying buttresses become necessary, springing over side aisles of different or of equal heights.

70. Flying Buttresses of 5-aisled Churches.

A different form of flying buttress with double side aisles, is that, where a common flying buttress spans both side aisles (Fig. 283), as on the Cathedral at Ulm and on Notre Dame at Paris (V-l-Duc, I-78). Usually, as on the Cathedral at Beauvais (V-l-Duc, I-70), the intermediate pier forms a mass of moderate section, loading the pier between the aisles, against which abut the flying buttresses of the centre and side aisles (Fig. 284). The outer flying buttress is not set at the foot of the inner one, but at the height of the intersection of the line of pressure with the gravity axis of the intermediate pier. The outer flying buttress is also usually made a round or pointed arch, and the inclined top continues in an unbroken direction to the buttress of the outer side aisle; the clearstory walls of the middle aisle may then be much stiffened by separating the inner arch from the inclined strut by vertical supports, as in New S. Peter's Church at Strasburg. (Fig. 285). Triple flying buttresses in combination with the arrangement of two side aisles were required on cathedrals of great height, as on the Cathedral at Bourges (Fig. 286; V-l-Duc, I-199).

Substitute for Buttress.

The entire system of buttress and flying buttress resulted from mediaeval vaulted construction; it gives to the churches in Gothic their distinctive stamp; it was an expensive means for fulfilling a purpose, which could have been attained in other ways; it almost concealed the true construction of the church in great cathedrals, as on the Cathedral at Cologne. For practical reasons and for economy, Late Gothic reduced the buttress to its minimum by moving it into the building, so that the walls of the side aisles might be pushed out as nearly to the face of the buttress as possible. This then produced a series of side chapels extending around the church as a nucleus. The flying buttress was concealed beneath the roofs, or was made of the simplest form possible, vaults were made as light as possible to lessen the thrust, and piers were so large that the line of pressure fell within them, and on the Church of S. Martin at Landshut the wooden construction of the roof was arranged as to very heavily load the clearstory walls of the middle aisle, thereby forcing the line of pressure within the nucleus of the pier.

Italian Gothic reduced the buttress to the most scanty dimensions, and with the exception of the Cathedral at Milan, sought to entirely avoid the flying buttress by the use of tie-rods between imposts of vaults, an ex

pedient very offensive to the eye. The Italians were so accustomed to quiet and simple subdivision of masses, that northern churches did not please them.

The Renaissance proceeded in the same manner, decorating all projections from walls by pilasters; it preferred to connect internal buttresses, more rarely external, by semicircular niches, and thus treating the exterior in an original way, and properly arranging the interior. That it imposed on vaulted construction is an untrue characteristic by kk using the pilaster is to be pardoned, and also that it could not adopt the rude Early Christian pilaster, expressing the nature of vaulted construction as a pilaster.

SECTION 5. FORMS OF PLAN.

71. General Remarks.

By understanding the forms of ceiling, we obtain insight into the forms of plan. The two basal motives of all arrangements of plan are the longitudinal plan or rectangle, and the central arrangement, which may be a circle, square, or regular polygon. All plans are produced by subdivision, an interior into parts, or by addition of parts to form a whole. If it exceeds a certain magnitude, an oblong room must be divided by supports in accordance with the form of its ceiling, most simply by a row of columns or piers dividing the room into two equal or unequal aisles, producing a two-aisled interior with aisles of equal or unequal height. Larger interiors would next be divided into three or more aisles, which might be of equal height forming a hall design, or might form a basilican design, either having a higher middle aisle without side light or one with clearstory windows. Exactly similar results occur in case of polygonal and circular buildings; those with a central pier may be designated as two-aisled, those with one circle of piers around the centre as three-aisled, and those with two circles of piers as five-aisled buildings. Central buildings with clearstory windows may then be termed basilican, or those without clearstory windows are designs with a higher central aisle.

The other method, obtaining the motive of the plan by addition, produces a series of forms, all used in mediaeval architecture. From the simplest figure, the equilateral triangle, plans (Figs. 287, 288) may be produced by addition of triangles, squares, or rectangles. From the square result by addition (Figs. 289, 290) the varied form of Latin cross. Taking the circle or polygon as the basis, we may obtain central buildings with three or more aisles, which in combination with the Latin cross were used in rich Gothic buildings.

Principle of Choir-Ending in large Gothic Churches.

Already in Early Christian art are the three most important motives given for polygonal central buildings, which find their highest development as forms of choir-endings in Gothic cathedrals. These are the motives from Ottmarsheim, from S. Vitale at Ravenna, and from Aix-la-Chapelle, Figs. 1, 2, 3; parallel polygons with trapezoidal bays, as in the Church at Ottmarsheim, parallel polygons with square (trapezoidal) and triangular bays, as at Ravenna, or lastly, like the motive of the Cathedral at Aix-la-Chapelle, polygons with angles opposite sides, with square and triangular bays.

A brief expression is required to characterize for polygonal choir-endings their form and their connection with the nave. If the choir ends with 2, 3, 4, 5, 6, 7, sides of the octagon, we shall speak of a 2/8, 3/8, 4/8,

5/8, 6/8, or 7/8, choir-ending, and in general we shall indicate by a fraction m/n the ratio of the number m of the sides used to the total number n of the sides of the polygon.

The Ravenna motive is most common; it is used in a series of French and German cathedrals as the motive of choir-ending with different forms of polygons; thus for the inner 5/8 choir polygon of the Cathedrals at Halberstadt and at Milan, for a 5/10 choir in the Cathedrals of Madgeburg, MUnster, Vezelay, and Leon in Spain, and for a 7/12 inner choir-ending in the Cathedrals at Amiens, Cologne, and others. The Ottmarsheim motive is shown by the Church of S. Remy at Rheims (Lubke, 495); in a somewhat different form in the choir of the Cathedral at Bourges, 5-aisled with a 5/10 choir-ending, the squares of the choir aisle being replaced by trapezoids (V-l-LucII-295).

The polygonal system of Aix-la-Chapelle finds frequent use as a motive of choir endings in Gothic, as for the inner 4/8 polygon in the Church of Heiligengeist at Landshut in Baveria, for the 5/8 polygonal choir in the Abbey at Zwetl and in the Church of S. Sebald at Nuremberg, then on the choir of the Cathedral at Le Mans with its 7/14 choir-ending (V-l-Duc, II-353). The same motive occurs in somewhat unusual form in the choir of the Church at Collin, which shows 4 sides of the octagon internally, adjoined by 8 trapezoids and a triangle, producing a pentagon, to which are added parellel trapezoids and triangles. If the Ottmarsheim motive be varied by arranging equilateral triangles on the sides of the polygon instead of squares, filling the vacancies by triangles, a form results (Fig. 291), that occurs in the 3/8 inner choir polygon in the choir of the Cathedral of Freiburg-i-Baden, as well as in the inner choir aisles of Notre Dame at Paris and of the Liebfrauen Church at Worms.

If alternating squares and triangles be arranged around the polygon and the vacancies be filled by triangles (Fig. 292), a form is produced, found in the 3/8 choir polygon of the Frauen Church at Ingolstadt. A peculiar arrangement results from a series of hexagons in a choir polygon (Fig. 293), for the 5/8 choir ending of the Cathedral at Schwerin, for the 3/8 choir-ending employed in the Church at Sierikzee in Holland, and also for the Church at Dargun. Besides simple oblong rooms, antiquity was acquainted with halls with two or more aisles, simple circular and polygonal buildings, circular temples with several aisles, and also with great architectural groups, composed of combinations of the most different rooms.

Latin and Greek Cross Plans.

Early Christian architecture added to plans already known the Greek cross and the Latin cross. It also liked the polygonal building with one or more

aisles, generally produced by division, only the Cathedral at Aix-la-Chapelle being formed by addition. Plans with two aisles seem to have been little used in Early Christian art.

Circular buildings covered by a single vault of moderate dimensions are very common in Romanesque, and with polygonal plans are not rare in Gothic; polygonal structures covered by a vault of wider span occur only in S. Gereon at Cologne, in the octagonal Karlshofer Church at Prague, and in the 12-sided Church at Ettal in Southern Bavaria; the partly erected Church of Schöne Maria at Regensburg was planned as a hexagonal, two-aisled Gothic central building, and the Church of S. Gertrude at Wollgast was built as a 12-sided Gothic structure.

The favorite motive of the Greek cross in Early Christian architecture was seldom employed in the Romanesque, and only in smaller structures; but it became of importance in Romanesque as a motive for the form of choir in Rhenish churches, as in S. Maria-im-Capitol and Great S. Martin at Cologne, in the Church at Klosterrath, and in the western choir of the Cathedral at Mentz, also in one Gothic building, the Church of S. Elisabeth at Marburg. The Liebfrauen Church at Treves is a Gothic structure in form of a true Greek cross, an exception to the rule. Romanesque churches with two aisles are very rare, but are more common in Gothic.

The most common form of plan in Romanesque and Gothic is that with one or more aisles, arranged in form of the Latin cross; all conceivable variations from this type of plan were executed, according to local conditions and to the arrangement of divine service. In Early Christian and Romanesque architecture, basilican plans were usually entirely free from all restraint, so long as covered by wooden ceilings; but in Romanesque the system of the plan was strictly limited by the introduction of vaults; two square bays of the side aisle usually correspond to one square bay of the middle aisle; only rarely as in the Abtey Churches at Laach and Heisterbach, are the vaults of the centre aisle constructed over rectangular bays; Gothic freed the plan from the restraint of the square groin vault and permitted a freer movement without losing the severe unity of the system. Plans in the Gothic style are distinguished from those in Romanesque by a general reduction of masses of all walls and piers.

To mediaeval architecture the Renaissance owed the organic development and harmony of the plans of its churches; as already stated, it returned to Roman forms of vaults, but most completely developed the motives of the central building and of the plan with 2 or 4 apses received from mediaeval and Early Christian architecture. As for the plan of the church in detail, its simplest form comprises the church proper and the choir. Be-

fore the nave is sometimes placed a vestibule, and between it and the choir is a transverse aisle in larger plans. Interiors with one or more aisles are to be vaulted in both ecclesiastical and secular structure, and one or more towers are usually added to churches.

We therefore treat the following points in detail:-- 1. Plans with one aisle; 2. Plans with two aisles; 3. Plans with three aisles; 4. Endings of side aisles; 5. Plans with more than three aisles; 6. Transepts; 7. Plans of choirs with choir aisles and a circle of chapels; 8. Unusual and irregular choir-endings; 9. Plans of towers.

72. Churches with Single Aisle.

The choir is the space in which the clergy remain during divine service, and the nave is that for the devout multitude. The choir may in its simplest form serve as a nave also, be built as a chapel adjoining that, or be entirely omitted, the altar being placed in the church itself. The choir would in all these cases be changed into a separate chapel.

Chapels in general are buildings already from the earliest Christian period built in memory of saints, or they are connected with dwellings, castles, bishop's palaces, hospitals, bridges, etc.; there are domestic and castle chapels, palace and hospital chapels, or country and churchyard chapels, or they may be additions to churches and connected with them as parts of churches; they are then not loosely joined to the church, but are included therewith in the general plan; we likewise arrange them with nave and choir in larger churches.

Since the esthetic treatment of these simplest designs of churches and chapels is entirely independent of the purposes served by them, we shall consider them together. The simplest form of churches and chapels with a single aisle is square or circular, as in many examples from Romanesque and Gothic. Romanesque circular chapels are especially common in Austria as sepulchral chapels, in imitation of the Chapel of the Holy Sepulchre in Jerusalem, and repeatedly occur in Germany; Gothic employed Polygonal instead of circular chapels; triangular ones are rare, but occur at Bruck-a-Mur and in the neighboring Breitenau; hexagonal and octagonal are more common. The simplest mode of extending these chapels is by addition of one or more apses, semicircular in Romanesque or polygonal in Gothic. An interesting example of a Romanesque triangular chapel with semicircular apses is found at Planes in Roussilon (V-l-Duc, II-443, 444). Square Romanesque chapels with three or four apses are the Chapel of S. Croix at Montmajour near Arles with four (V-l-Duc, II-445-447), as well as the Chapel of S. George (Allerheiligen) at the Cathedral of Regensburg with three apses. A square room with four rectangular wings occurs at Schwartz-Rheindorf. A square

Gothic chapels with a 5/8 apse are the Chapel of Regiswinden at Laufen on the Neckar, the Chapel of S. Barbara-in-Walde near Dippoldiswalde (Beit. Taf. Fig. 7); with two 5/8 and two 3/8 polygons, the Castle Chapel at Marburg in Hesse, (Beit. Taf. 59, Fig. 3).

Examples of hexagonal chapels with apses are the City Hospital Chapel at Hof near Regensburg (Beit. Taf. 58, Fig. 14), at Avioth (V-l-Duc, II-448-450), and on a three-aisled plan, the beautiful Castle Chapel of S. Mathias at Cobern on Moselle. The Fountain Chapel in the Cloister at Maulbronn is 9-sided, and octagonal chapels are common in Gothic; the Chapel at Laufen in the Salzkammergut is square below, 8-sided above. The Castle Chapel at Vianden is 10-sided; an 11-sided building of the transition style is at Tuln, and 12-sided plans are not rare in Gothic.

A further advance in treating centrally arranged interiors is the arrangement of four squares around a central pier, as in two beautiful domestic chapels at Regensburg, one called "am Römling" (Beit. Taf. 50, Figs. 1, 2), the other in the Gasthof zum-Weissen-Hahne, also in the Hospital Church at Cues and in the Chapter Hall of the Monastery at Eberbach (Ungew. Figs. 575, 576). In the two latter the interior is covered by a star vault. A still larger central chapel or church interior requires subdivision into nine bays with four piers, producing a 3-aisled room recalling a byzantine plan, like the Castle Chapel at Donaustauf (Beit. Taf. 50, Fig. 3). This interior is extended on two opposite sides by three semicircular apses with three niches on each.

The simplest room is produced by arranging two square vaults beside each other, as in the Romanesque Oratory of the Abbot of S. Gall at Regensburg, then by arranging three vaults with or without a choir apse, an arrangement usual in many chapels and smaller churches in Romanesque and Gothic. (Beit. Taf. 49, 50, 58). Two rectangular bays beside each other form the basal motive of the Castle Chapel at Freiburg-a-U. If the choir apse occupies the entire width of the interior of the Church or chapel, we then obtain the next important form, that of a Gothic chapel with single aisle, also of churches and choirs, whose finest example is the S. Chapelle at Paris.

Dimensions and Details of Plan of Choir.

Rules for determining dimensions for such plans of choirs have been preserved from the later period and are interesting. If a be the clear width of the choir, then 1/10 a is the thickness of the wall as well as the thickness of the buttress. Its projection is 2/10 a, twice the thickness, or this may be made equal to diagonal of a square with side 1/10 a. If the buttresses are omitted, assuming the best technical construction, the extreme limit of permissible thickness of the wall is 1/7 a; also diagonal

of square with side a is to be taken as the extreme height of the springing of vault. For the choir polygon, the span vault-rits equals the half diagonal of polygon, and according to the same rule, the projection of choir buttress increases in like proportion, since in Fig. 294, ab : ab' :: ac : ac'.

Another rule for the projection of the buttress, valid in the middle ages, in some measure corrects proportions by the preceding rule, and is that the pointed or round arch be divided into three equal parts a a, a aß'(Figs. 295,296), and the projection a i be assigned to the buttress. For the round arch, the projection of the buttress will then be one-fourth, and for the pointed arch, somewhat more than one-fifth the span.

All such rules give sufficient thickness for small buildings; in larger structures like the S. Chapelle at Paris, the projection of the buttress at the floor, together with the thickness of the wall and the projection of the piers, is about one-third the clear span of the transverse arch, about twice the clear width of the room being the height of the vaults. Strongly projecting buttresses are advisable, since they not only increase the effect of strength in the general appearance of the building, but likewise permit slight projections of wall-piers into the interior, thereby saving space and stone-cutting. It will be safest to accurately construct the line of support in the different cases and then determine the depth of the buttress.

Windows occupy the entire space between the buttresses when designed to have rich stained glass, as in most French buildings, or it is intended for either the surface of the windows or that of the walls to decidedly predominate, as when one-third the side of the polygon of the choir is taken on as the width of the window. The width of the different divisions of the window varies between 20 and 6 inches; windows of the older Gothic buildings generally have broad glazed spaces, which make the tracery simple and imposing. The middle window of the choir is usually distinguished from the others by being wider or decorated by richer forms of tracery.

The interior may be made wider if the buttresses partially project inside (Fig. 297), the walls then being moved outward; a smaller external projection of the buttress then occurs. Walls may be lighter, saving material and work, if niches are formed in them beneath the windows, or on the exterior the window plane is set in a recessed niche, as in Figs. 283, 284, an expedient frequently employed in Gothic. Both methods of reducing wall and enlarging interior may be combined (Figs. 298, 299, 300, 301), as on the Church of S. Johann at Maestricht, and these niches in the interior may also be transformed into complete chapels with special windows, as

on the Church of S. Katharine at Oppenheim. If we retain the principle of arranging in the interior of the room as many small shafts as there are ribs or arches, in the simplest case (Fig. 302) only one shaft is required in each angle of the choir, with a group of shafts or a larger shaft in place of this, on the exterior of the choir. But since the buttresses a' a' lie in the direction of the arches and not in that of the ribs, the intervals between the external buttresses would be unequal, as well as those between the internal shafts, so that d' e' is greater than a' d' and this is greater than a' c' on the exterior, if in the interior a c is made equal to a d and to d e', then will the single and grouped shafts have unequal distances between each other, if the polygon be laid out with geometrical accuracy. Then either windows or walls are unequal in width on the exterior , if the windows are set in the middle of the wall, or either unequal window jambs or unequal sides of the polygon result, if the former are made equal. The length of bay in the choir-ending equals a side of the polygon with reference to this relation; but since the length of bay for a constant width of the aisle diminishes as the number of sides of the polygon is increased, then to harmonize the dimensions, we have the choice of making the polygon irregular, of taking the length of bay at pleasure, or of making the choir polygon of such a form, that more than half the number of its sides are actually employed, thus arranging 4/5, 5/6, 6/7, etc., or 5/7, 6/8, 7/9, etc., choir-endings."

Since the buttresses of the choir have to resist a smaller thrust than the buttresses of the nave, they may be made lighter than the latter. But in the later middle ages the same dimensions were assigned to choir buttresses and nave buttresses; the former could then be enriched by pinnacles, etc., to make their masses appear lighter.

The length of bay for interior of the church is usually so taken that the span a b of the aisle equals diagonal of square of length of the bay, or equals 1/2 a b, or in any other advisable ratio, The thickness of wall must increase in proportion to length of bay, to ensure bonding with the buttresses; in old buildings, this is from 1/5 to 1/7 the length of bay. The number of bays depend in the desired extent of the interior, and to obtain a richer appearance of the church, this would rather be increased than diminished for a given length, so that three or four rectangular bays would always be prefferred to two square ones.

Rectangular Ending of Choir and Nave.

If a rectangular church or choir be enclosed by a wall, two buttresses will be arranged at right angles at the angles (Fig. 303), or a single buttress be set on the diagonal of a square (Fig. 304); the buttresses first

form a continuation of the wall (Fig. 305) or may be set back from the angle to afford direct abutments for wall-arches (Fig. 305 a) and to strengthen the western enclosing wall of the choir, church, or chapel.

Location of Staircase Towers.

An appropriate expedient for strengthening the western wall is supplied by staircase towers, required for access to the attic or to an organ gallery. Taking one of the western angles with its buttresses, the staircase tower may stand in the angle a (Fig. 305) formed between the buttress and the wall, on the axis of the buttress at b, between the buttresses at c, or at the end of a buttress set diagonally at d. Which arrangement is preferable depends in each case on suitability and taste. In many Austrian Gothic churches, two staircase towers are arranged to strengthen the western facade. The arrangement at a may have the disadvantage, obviated by that at b, that the window of the first bay must be narrower than those of the other bays, or the first window may be but a half window, as on the Cathedral at Cologne.

Connection of Choir and Nave.

If the nave be wider than the choir, it ends with the "triumphal arch" (Fig. 306 b), whose symbolic meaning is that" it gives access to the place where the triumph of Christ over death is celebrated". If we do not make this the entire thickness of the wall, so that choir and nave are separated by projecting piers, but wish to connect together choir and nave (Fig. 307), it would be proper to introduce a rib a b to oppose the one-sided pressure of the choir rib c b. The triumphal arch is either supported by piers beneath it, or is simply treated up to the springing, where it is richly moulded and rests on corbels.

73. Churches with two Aisles.

First the increase in space requires two-aisled churches, and then too great width would be as bad as too great length of an interior with a single aisle. In two-aisled churches, the choir-ending admits of a special arrangement. In many cases, especially in two-aisled churches with wide main and narrow side aisle, a choir-ending is placed at each end of main aisle (Fig. 308). In two-aisled buildings with aisles of equal width, these end in two choir polygons (Fig. 309); beit. Ta . 57, Fig. 4) as in the Church of S. Sophia at Dresden, and the angle between the choirs may then be filled by a staircase tower (Fig. 310), as in the Bruder Church at Kampen in Holland, by a sacristy (Fig. 311), as in the Church at Vollenhoven in Holland, or a small choir polygon may be inserted between them (Fig. 312), as in the Heiligengeist Church at Passau (Beit. Taf. 57, Fig. 8); the two-aisled church may be changed into one with three aisles (Fig. 313) as in

the Parisian Church at Emns; or one choirpolygon may be placed at the centre of nave and separated therefrom by a triumphal arch as at Namedy, or the vaults of the choir and nave unite, as at Bornhofen on the Rhine (Fig. 315).

Three hexagonal chapels may be introduced as extensions of the choir (Fig. 316), a two-aisled interior with triangular groin vaults may terminate with two sides of the hexagon (Fig. 317), or a common half hexagon or another polygon may be taken as the choir-ending for both aisles (Fig. 318). The two-aisled plan ends at the west with a wall divided by a buttress; this buttress is loaded by a gable tower or replaced by a staircase tower; the facade has a common or a double gable; the roofs may be either treated as a single roof or as two parallel roofs, to avoid too great height of roof, then being separated from each other (Fig. 319), as on the church at Vollenhofen, or be connected together at the east end (Fig. 320), as on the Abbey Church at Middelburg in Holland. Some of these motives of choir-endings may likewise be employed for the western end, thus producing peculiar forms of facades connected with a western tower.

74. Plans with Three Aisles.

The 3-aisled plan was so arranged in Romanesque that the bays were square, two bays of the side aisle corresponding to each bay of the middle aisle; the early transition and Gothic styles usually made the vaults of the middle aisle hexapartite. This ratio of 1 : 2 of side to middle aisle is most suitable if side ailses are arranged, since both hexapartite and oblong groin vaults with ratio 1 : 2 correspond to the square groin vaults of the side aisles (Fig. 52). Gothic architecture freed itself from the restrictions of the ratio 1 : 2, and if we wish to fix 1 : n at pleasure, as 1 : square root of 2, so that width of the aisle equals diagonal of square of length of bay, retaining square bays of side aisles and 3-aisled transepts, we should always obtain a regular plan (Fig. 321, left), less severly restricted than the former; but if we wish side aisles also to have oblong vaults, a rectangular area a b c e f g K(Fig. 321, right) would be produced at the angles between the side aisles of nave and transepts, which might be a perfect square a b d g or a truncated one a b c f g. This also occurs in plans with more than three aisles. This restriction may be avoided by making the bays sufficiently long and arranging square bays where side aisles of the nave and transept intersect (Fig. 322). This produces five kinds of bays, which is again true of churches with more than three aisles. The length of bay in churches with several aisles is fixed by the plan of the transepts, and these relations also influence the width of windows, etc. The length of interior of a church with several aisles also depends on the

requirements, and is usually fixed, so that the form of Latin cross six squares is approximately attained, the length predominating, rather more than fewer bays being used.

75. Ending of Side Aisles.

The Romanesque had fixed on an apse as the ending of both middle aisle and of each side aisle by smaller ones as in the Gothic also; the side aisles merely end square or apses are placed side by side (Fig. 323), as in S. Peter at Straubing and other churches. The more developed plan inserts a square choir (Fig. 324), which the principal apse adjoins; this apse is sometimes omitted and the middle aisle ends with the square choir (Fig. 325), as at Limburg-a-H and at Oberstenfeld (Lubke, p 404). A third motive occurred early in France, and is that with choir aisle; instead of side apses, the side aisle continues around the main apse in a continuous circuit (also in S. Michael at Hildesheim), in southern France buildings usually extended by radiating chapels, first found in Germany in S. Godehard at Hildesheim. Another motive for choir-ending is produced by enlarging the choir by three great apses, as on S. Apostles at Cologne, western choir of Cathedral at Mentz, and in the Church at Klosterrath. This idea is combined with that of choir aisle to produce the beautiful plans of S. Maria-im-Capitol and of Great S. Martin at Cologne, not carried further in France nor in Gothic, but was perfected by the Renaissance in the plan of S. Peter at Rome as a quadrangular design with choir aisles.

Gothic Choir-Endings.

The essential point in the Gothic choir-ending is that it transforms the romanesque semicircular apse into a polygonal choir, producing new arrangements, in connection with setting the polygonal diagonally. The common form is the 5/8 choir-ending (Fig. 326) with or without the square choir (Fig. 327). A change of this motive with wider choir is found in the Church of S. Aegidius at Regensburg (Fig. 328). By setting side polygons diagonally, a new form results (Fig. 329), repeated four times in the plan of the Liebfrauen Church at Treves.

These variations increase, as polygons with different numbers of sides are employed. The angles formed between buttresses at the junctions of the polygons give opportunity for staircase towers, but may be entirely avoided, if as at Wiesen Church at Soest, the principal polygon be treated as a 4/5, 5/8, 6/7, or 5/7, 6/8, 7/9, etc. choir-ending (Fig. 330). A peculiar plan of staircase tower is in the Church of Nagy Karoly in Hungary (Fig. 331).

76. Transepts.

The transverse aisle was originally the special place for the clergy,

and the choir consisted merely of the sanctuary or apse. The oldest Romanesque building with a single transverse aisle, the Church of S. Remy at Rheims, (10 century), which retained the plan of S. Paolo-f-l-Mura at Rome, introduced a new element, the three-aisled transepts and eastern chapels (V-l-Duc, IX-217). At the end of the 12 century this plan was changed, the choir aisle was arranged, and the clergy were restricted to the intersection and choir, while the congregation were also permitted to occupy the transepts. The choir aisle was now a necessity to connect the transepts behind the sanctuary, and the transepts were much extended,to receive crowds of pilgrims collecting during the crusades, who desired to see the relics of the saints then exhibited in the choir. Cathedrals founded in the 12 century in Isle-de-France were chiefly arranged without a distinct transverse aisle, and in central France but few cathedrals had the privilege of a plan with transepts. Even Notre Dame at Paris was originally planned without transepts. Monastery churches almost always had transepts in the early middle ages. In the later mediaeval period, transepts were only arranged to increase the space.

The length of bay of nave was usually retained as length of bay of transepts. The intersection was marked by massive piers and was usually crowned by a tower, or two towers in Rhenish cathedrals with double choirs and some Saxon churches, one over the western and the other over the eastern intersection. The width of transverse aisle is generally the same as that of middle aisle of nave, though there are many variations from this rule. The projections of the transepts is same as the width of the nave, so that they only project free beyond the side aisles in buildings with several aisles, or is usually greater than the width of the nave. The form of piers in transepts is readily deduced from general principles given for arrangement of piers. Two sets of transepts are rare, as at Heisterbach and Salisbury.

Transepts either have a single aisle, even in great churches, as in the 5-aisled Notre Dame at Paris, and the 7-aisled Cathedral at Antwerp; seldom have two aisles, as at the Cathedral at Strasburg, the Church of S. Burkhardt at Wurzburg, also in England, (Beit.Taf.59,Figs.1,2), but are commonly three-aisled. They chiefly terminate with a straight facade, are semicircular in Rhenish triapsal plans, or rarely polygonal in Gothic, as at Noyon, on the Cathedral at Tournay, on the Church of S. Elisabethat at Marburg, and the Heiligenkreutz Church at Breslau. In Italian buildings, transepts frequently end in one or more apses.

77. Plans of Choirs with Choir Aisles and Chevet Chapels.

Earlier French choir aisles were extended by a series of distinct semi-

circular chapels; in the choir aisles of the Abbey Churches of S. Denis and Vezelay, as well as in S. Martin-des-Champs at Paris, the chapels first combine in a complete series of chevet chapels, but remain semicircular. The chapels are in the interior connected together by a passage. At S. Martin-des-Champs, the middle bay of the choir is wider than the others and affords access to a separate chapel of the choir, imitated and called the Chapel of Mary (Lady's Chapel) in the perfected Cathedrals at Rheims, Amiens, and Beauvais, erected between 1230 and 1270. The choir of S. Germain-des-Pres (1163) was the first in polygonal form. In these cathedrals, the chapels were polygonal and no longer connected by a circular passage, but separated by division walls. Peculiar arrangements of these chevet chapels are in the Cathedral at Rheims, where each chapel is planned for an oblong vault; but they here have common division walls; in the Cathedrals at Le Mans and Sees, these chapels are detached around the choir aisle, each with its separate walls. Finally, in the Cathedrals at Chartres, segmental and semicircular chapels alternate. In the Church of S. Remy at Rheims, the chapels are externally rounded and internally join the choir aisle in circular form.

If the choir aisle be a 5/8 polygon of perfectly regular form, and the choir piers be set on the diagonals of the polygon, five sides of the inner octagon will be equal; if the nave be divided in bays, the last bay of the middle aisle is either considerably larger than the others and the last bay of the side aisles is irregular (Fig. 332); or a half bay must be inserted, receiving an inserted acute-angled side aisle vault (Fig. 333). It was sought to avoid both by joining the 5/8 choir-ending directly to the square ending of nave, drawing the diagonals of the polygon, omitting the inner polygon parallel to these and the piers a inserted in Fig. 333. Then in Fig. 334, there were three equal sides a b of the inner choir polygon and two sides b c differing from these and from the length of the bay c d. If the inner polygon was made regular and directly joined to the nave, then two sides of the external polygon were smaller than the others and larger than the length of bay (Fig. 335), producing three larger and two smaller chapels, if a series of chevet chapels was to be arranged. But if the sides of the polygon were made equal externally and internally, this returned to the case of Fig. 332. The arrangement in Fig. 334 is therefore preferable to all others and is that usually employed. These difficulties of the choir-ending of the nave disappear, if in the fraction denoting the number of sides used and the total number of the polygon, the denominator be made twice the numerator, or 3/6, 4/8, 5/10, 6/12, 7/14 choir-endings be employed (Fig. 336). The choir then directly joins the nave and the

internal and external sides of the polygon are respectively equal. Ratios with numerator not divisible by 2 are preferable to others and permit the addition of an eastern chapel, so that 5/10 or 7/14 choir-endings may then be taken as normal (Fig. 337). In larger Dutch churches, 5/9, 5/10, 7/12, choir-endings are most preferred. Since choir polygons require smaller buttresses and flying buttresses than bays of the nave, as only one vault rib abuts against the choir buttress, in contrast with two ribs and a transverse arch against those of the nave, choir piers in choir aisles need not be as strong as piers of the middle aisle of the nave. Since if A (Fig. 338) denotes the nave pier with its shafts a a, the shafts b b correspond to the pier in the choir (a 3/8 choir-ending here), but if the shafts supporting transverse arches must be symmetrically arranged about the middle of side of the polygon, there sometimes result choir piers composed of two circles, as in the Cathedral at Cologne and in S. Gudule at Brussels; the reason for this is evident, if the construction be assumed; for in Fig. 339, c d is greater than a b.

To lessen the irregularity of sides of the polygon in the arrangemet of Fig. 336, an intermediate pier was inserted in S. Gudule at Brussels, three pentapartite grein vaults being arranged in the choir aisle (Fig. 340). The chapels are then omitted, double chapels must be arranged, or as in S. Remy at Rheims, in Notre Dame at Chalons, in the Cathedral at Auxerre, and in the Church at S. Quentin, the chevet chapels may be separated from the choir aisle by a series of columns. (Fig. 341). To avoid evils resulting from arrangements in Figs. 332 - 335, it was simplest to exchange the primary motive of Ottmarsheim for that of the Cathedral at Aix-la-Chapelle, or that of Notre Dame at Paris, thus arranging instead of trapezoidal bays those alternately square and triangular, or those exclusively triangular.

The most perfect expedient for avoiding the difficulties mentioned, and which produce irregularities in the leading of vaults, is that to make all sides of the three polygons a, b, c, Fig. 342, but if the middle polygon c c c is assumed to be regular, this indeed gives equal sides to the others, but unequal angles; then will outer and inner polygons be irregular, and the choir aisle will have a different width in each bay. (Fig. 342). If bays are to be of equal widths, then to adjust this in some degree, we take sides with equal angles of the polygons; according to this very imperfect principle, the choir of the Monastery Church at Altenberg was actually planned.

The choir piers of the choir aisle have their centres on the circumscribed circle of the inner polygon, if this be regular, or on the inscribed circle, so that in the first case (Fig. 343) the first side A b of the

polygon forms the extension of the side arch of the middle aisle, but in the second is inclined slightly to the axis of the centre aisle (Fig. 344).

If the outer polygon be regular, then is the centre of the inscribed circle corresponding to the inner irregular polygon the same as the centre of the regular polygon; then a b = a d = 1/2 a c. (Figs. 345,346).

With radius A a transfer point a (Fig. 346) to b', and likewise transfer the pier from b to b'; this construction is the basis of the choir of the Cathedral at Cologne, and of its prototypes also, the Cathedrals at Beauvais and Amiens, as well as their imitations, especially of the Church at Kampen. This construction of Fig. 346, like that of Fig. 334, has the advantage over the others, that the point a is moved back towards the choir-ending, thus opposing to the 3, 5, or 7 choir ribs A b, two ribs A c of greater span and exerting greater thrust. For the same reasons, the builder of the cathedrals with 5/10 and 7/14 choir-endings placed the apex of the choir vault, (Fig. 347) not on the line a b, that the choir ribs would abut against the transverse arch a b, but to approach in some degree the centre of gravity S of the figure a b c d of the plan; even in plans like Fig. 334, these circumstances were taken into account, when the keystone approached the centre of gravity of the bay of the choir vault (Fig. 348, full lines), both in French and German buildings, in the Cathedral at Amiens, as well as in the Cathedral at Cologne.

The usual form of chevet chapels produces wege-shaped division walls, which act as buttresses of the vaults of the side aisles; in very large churches these buttress masses are larger than necessary; they are then turned outwards so that the main piers of the chapels become free, as in the Cathedrals at Amiens and Beauvais, or the interspace between the chapels is entirely opened and covered by a separate vault (Fig. 351). Thus are the chapels of the Cathedral at Coutances arranged. In the Cathedral at Le Mans the buttresses are entirely omitted, since the walls of the chapels afford sufficient abutment. Windows are opened in the walls between the chapels. Two flying buttresses result in both cases instead of a single one.

If the division walls between chapels are strengthened and very strong abutments are thus formed, the buttresses are drawn in quite between the chapels (Fig. 349), as in the Cathedrals at Amiens, Alby, and Rheims. If we use 4/8 or 5/10 chapels, enclosures of moderate size are formed between them (Fig. 350). If the buttress be entirely drawn into the interior, this is generally between rectangular chapels, as in a series of large churches in Holland, as well as in many Bavarian churches with alternating square and triangular bays in the choir aisle. Many Dutch churches, especially

those of the province of Zealand, continue the rectangular chapels along the side aisles; the same occurs in Spanish cathedrals with polygonal chapels. The angles formed by junctions of choir aisle and chevet chapels with the extension of the choir or with those of the transepts, are especially suited for the arrangement of staircase towers, which may be placed at other points of the choir. Plans of piers in the choir aisle naturally result from a consideration of the plan of the pier in general, if we adhere to the law that to every rib corresponds a shaft, to every arch of double size a larger shaft, to every triple arch a group of shafts, etc. Wall arches receive separate shafts.

78. Unusual and Irregular Choir-Endings.

The rectangular choir-ending, which the Cistercian order preferred for its churches, was rarely justified in mediaeval cathedrals; it was too plain for these great churches and only corresponded to the limited requirements of monastic churches. Even in France, it was indeed seldom employed in monastery churches, which preferred the choir aisle with chevet chapels; only the mother Church at Citeaux and the Church of S. Julien at Tours, rebuilt in 13 century, are given by Viollet-le-Duc as monastery churches with rectangular choirs (V-l-Duc, I-271, 303). Of larger cathedrals, the Cathedral at Laon, of smaller churches, that at Dol in Brittany. In Germany as well as in France, the rectangular choir occurs during the Gothic period only in small churches alone, and then for sake of economy. Among English cathedrals, those at Durham and at Salisbury end in rectangular form, in Italy, the Cathedral at Sienna.

Viollet-le-Duc mentions two notable examples of combinations of rectangular choir-endings with apses; the Church at Taur in Toulouse from end of 14 century ends with two choir polygons (Fig. 352) connected by a straight terminal wall (V-l-Duc, I-9). The Church at Tour surrounds the polygon of the side aisles by a choir aisle, between which the choir ends square (Fig. 353; V-l-Duc, I-8). The Church at S. Etienne at Beauvais adds a central choir polygon to the rectangular choir-ending with cut-off corners, like the church just mentioned (Fig. 354), and covers the inner side aisles by triangular vaults, the outer ones by a transition with trapezoidal and triangular vaults to the rectangular choir-ending (Ungew. Fig. 305). The Frauen Church at Bruges consists of a regular 5/8 choir with choir aisle, adjoined on the east by a 5/8 chapel, also by four irregular pentagonal chapels (Fig. 355), so that the rectangular choir-ending is substantially reproduced here. The 3-aisled Church at Goes in Holland with a row of chapels along each side aisle is changed in the last bay into a 5-aisled church, and the middle aisle as well as the southern and northern paits of side aisles end in 5/10

chorus (Fig. 353). In the Church of Marienwerder in Holland, the choir has a gallery without aisles (Fig. 354), projecting considerably beyond the lateral ones. The choir of the Frauenkirche at Ingolstadt (Fig. 355) has a more unusual arrangement of a triple aisle, the side ones being exactly similar to the nave aisles. Fig. 356 gives a more unusual solution of the same problem. The choir of Freudenstadt in Holland has detached chapels, resembling those usually found in Late Gothic.

Towers.—Among the parts most decidedly affecting the exterior appearance of mediæval churches, and in Early Christian times rarely existing at all, were towers, which were seldom introduced in Romanesque, or at the beginning of Gothic, and the earliest object of Gothic ingenuity and elaborate ornament. The Gothic always joined the towers to the church itself. Small and structural towers were placed at the most important points of the plan, as over the western and transept termini, or at the transverse junctions of nave and choir with the eastern choir or transept, as well as occasionally at intermediate points between the junctions of the latter, where they were rarely continued above the roof. Towers, though at first and chiefly, as time went on, were placed at the western end of churches, whether at first and chief, as time went on, as the principal entrance, or, as in Germany, at the eastern choir or transept, as well as occasionally at intermediate points between the junctions of the latter, where they were rarely continued above the roof. Towers, though at first and chiefly

choirs (Fig. 356). In the Church at Harderwyck in Holland, an inner 7/12 choir has a 9/12 choir aisle (Fig. 357), producing two triangular and 5 entirely irregular trapezoidal bays. The choir of the Franciscan Church at Salzburg exhibits the rare arrangement of a triangular choir-ending with 5/8 choir aisle. Fig. 358 gives a more suitable solution of the same problem. The Church at Brouwershafen in Holland has distinct chapels, occasionally found in Late Gothic.

79. Plans of Towers.

Towers are the parts most decidedly affecting the external appearance of mediaeval churches, and in Early Christian churches are almost always detached, which was seldom imitated in Romanesque, as at the Churches at Clermunster and of S. Emmeran at Regensburg. The Romanesque and afterwards the Gothic always joined the towers to the church itself. Bell and staircase towers were placed at the most important points of the plan, the angles of the western and transept facades, or if the transverse structure did not form transepts but merely contained several stories, as on the plan of S. Gall and the eastern choir of the Cathedral at Mentz, as well as S. Michael at Hildesheim, they were placed before the facades of the transepts. Especially appropriate for towers are the angles between nave and transepts, those of nave and choir; we find such on the Cathedrals at Spires, Worms, Bamberg, and Naumburg.

Another more suitable place for a tower was the intersection of a church of cross plan; such are very common in Romanesque, with two towers on churches with double choirs, but they were rarely employed in Gothic; as on Cathedrals at Laon, Geneva, Lausanne, Coutances, some English cathedrals, and in Germany on the Cathedrals at Regensburg and Passau; a spire was usually set in their place. A bell-turret or small tower sufficed for monastic orders and their modest requirements, and was placed at the side of the church or as a gable tower. Towers are seldom placed beside the nave nearer the choir, as on the Cathedral of S. Stefan at Vienna. The usual plan of churches was one or two western towers; rarer are those with towers in angles of choir and transepts or nave, as well as those with towers over intersections.

On smaller churches, as on the Church at Oberstenfeld, the tower sometimes stands on the choir square, adjoining which may be an apse. Western towers with a middle central tower are rarer, and are usually connected by a transverse structure in the north German lowlands, Thuringia, lower Saxony, and Westphalia, but are also arranged as double towers in the brick architecture of north Germany. Towers over intersections are relatively cheapest, only requiring sufficient intersection piers, developing an external

treatment only above the roofs; they were already in Early Gothic sometimes surrounded by four smaller massive staircase towers, a motive employed in Romanesque on Great S. Martin at Cologne, recurring at Bamberg, and Naumburg, and after the model of the Cathedral at Leon.

A single western tower before the middle aisle has great advantages over any other arrangement, excepting the intersection tower; it forms a perfectly symmetrical design, is also preferable economically, has spacious galleries and belfries with great width of middle aisle, imposing development in height, and for unreliable conditions for foundations as in Holland, has a greater assurance of stability than a design with two towers. It conceals the middle aisle and makes no pleasing addition to the western walls of side aisles; its prominence is justified as the western termination of the middle aisle. It always corresponds to the width of the middle aisle and may be built to project its entire depth before the centre aisle, or for economy, may be half or entirely included within the structure of the nave. In the first case it forms an open vestibule (Fig. 380), as on the Cathedral at Freiburg, in the second, an extension of the interior of the church to the west (Fig. 381), and in the third, is a separate tower porch (Fig. 382). The second and first cases may be so combined, that the tower forms an open porch and also the first bay (Fig. 383) open to the nave or separated by walls. An allied and more complex plan is shown by the Cathedral at Lausanne." These would be the same, if the towers were placed before the transepts; the simplest and most economical arrangement would then be to flank the intersection by two half projecting towers (Fig. 384), whose piers could also be the intersection piers.

The facade with two western towers before the side aisles is the most pleasing arrangement, and therefore is the one most employed; it not only has the advantage that the middle aisle may be clearly indicated by a gable facade, but between the towers may be inserted a porch, over this being a gallery for the organ choir. The Romanesque always preferred to build facades with two towers, at least in Germany, whenever the double choir did not give a preference for the design with four towers. The Gothic celebrated its highest triumph in the western facade with two towers. They either project their entire depth from the west facade (Fig. 385), or are partly included (Fig. 386), the first case for economy less preferable than the second or more common one and seldom used. - Yet at Friedburg, the very convenient porch and organ gallery are entirely omitted. The included towers sometimes have no porch, but extend the nave, as in the Cathedral at Regensburg. The western towers may have the same width as the side aisles, or may be wider, as chiefly the case in French cathedrals; this in-

crease in width larger German churches is usually not greater than the projection of the nave buttresses (Fig. 367); the porch is elsewhere made narrower to afford space for the thick walls of the towers (Fig. 368); in churches with buttresses included within them, between which is a series of chapels, the width of the tower is made equal to that of the chapels together with the width of the side aisle (Fig. 369).

In 5-aisled churches, the Cathedrals at Paris, Beauvais, and Cologne, the towers have the total width of both side aisles (Fig. 370), and the interior is covered by an octapartite groin vault, or four groin vaults spring from a central pier. In the 5-aisled Cathedrals at Troyes, and Tours, the towers are narrower than the total width of both side aisles (Fig. 371), and set diagonally (Fig. 372), as on the Church of S. Ouen at Rouen and on the Church at Ingolstadt. (Beit. Taf. 30, Figs. 1,2). In smaller churches, the tower frequently stands at the western end of one side aisle, and in churches with one aisle, before the western facade. (Fig. 374). It is then wider, of equal width, or narrower than the nave, according to requirements, and in the last cases its side walls serve as buttresses for the vaults of the church. An arrangement preferred for small churches is to place one tower beside one of the side aisles near the west facade of the choir, having an entrance, while the western facade remains without a portal, or it is connected with the sacristy, or its lower story is used as a council chamber, for archives, etc. Very small towers are gable towers and are corbelled out in any manner.

Towers generally contain stairways inside, increasing their stability; smaller stairs are added to them as staircase towers or ascend in the thickness of the wall; the staircase towers are then located to suit the choir or at the centre of the side of the tower. The winding stairs are sometimes placed in the interior of the church.

SECTOIN 8. INTERNAL CONSTRUCTION OF MEDIAEVAL CHURCH.

80. Interior of Nave.

The interior of the Romanesque and of the Gothic church is generally that of the vaulted basilica. The unit of the longitudinal section is a vaulted bay, the piers at the sides of the middle aisle being connected by round or pointed arches, which support the clearstory wall (Fig. 375). From the capitals of piers in vaulted basilicas, wall-piers of various sections extend up to the vaults and receive the arches of the vaults on springing courses or capitals. In the basilica with horizontal ceiling, these wall-piers are omitted.

The basilica with oblong groin vault, as first used at Vezelay about 1120, produces the simpler form with piers all alike (Fig. 375), since one bay of the side aisle corresponds to one of the middle aisle. With square groin vaults, two bays of the side aisle corresponding to one bay of the middle aisle, intermediate piers become necessary (Fig. 376). Alternation of two piers was already very common in basilicas with horizontal ceilings during the early middle ages. From this motive was developed the double arrangement of the bays of the vault, as first found in the Churches at Echternach, (Fig. 377) and Hirsau (Fig. 378), then in the Rhenish Cathedrals at Mentz, Spires, Worms, and also with the hexapartite groin vault in the Cathedral at Limburg-a-L. This double arrangement of vault bays first occurs in France in the Cathedral at Noyon in a somewhat extended form of the Limburg system and thence passes to other French cathedrals.

In churches with a single aisle, each bay consists of one vault supported by wall-piers; one or more windows are then opened in the wall, or as in many Gothic buildings, this is entirely omitted and replaced by a great window. Fine examples of bays over single aisles are afforded by the Church at Fontevrault (V-l-Duc, I-172) and the Cathedral at Poitiers (V-l-Duc, IV-255), where a passage is corbelled out beneath the windows and supported by a massive pointed arch.

Roofs of side aisles, slope from the clearstory walls of the middle aisle and were almost exclusively shed roofs; therefore the clearstory windows must be placed above their upper edge; this produced a large space between the windows and the arches connecting the piers; if these arches were not loaded more than necessary, openings could be formed in the intermediate wall and looking into the attic, or this intermediate wall could be used as a background for blind arcades, with suitable spaces for mural paintings; both methods could be combined, a gallery extending around the church above the side aisles and opening into the interior with sufficient width to form a passage and closed by a thin wall next the attic, or the space under the

roof might be developed into a gallery. There was a choice of plain walls, openings with windows, triforiums, or open galleries. These galleries and triforiums were liked in Late Romanesque; the triforium was especially used in Gothic. When a greater number of attendants were required in a church with a small ground area, the triforium also extended around above the gallery. This produced four-story churches, as in the Cathedral at Limburg and many Rhenish churches, like the Church at Boppard.

In the Cathedral at Mentz (1138-1150), the pier between two bays of the side aisle is continued above its impost block to form wall-niches below the clearstory windows, and is then connected with the nave piers by round arches (Fig. 379); in the Cathedral at Worms (1172-1181) these arches over wall niches enclose the windows, no longer combined in a group, as in the Cathedral at Mentz, but falling in the axes of the bays of side aisle (Fig. 380; V-l-Duc, IX-245). In the Cathedral at Spires, to the dividing pier of the side aisles is added a half round shaft with capital, a small window being opened above the clearstory windows into the external dwarf gallery (Fig. 381; Lubke, G. A.-355). In the Cathedral at Limburg, (1212-1250), which substantially agrees with the Cathedral at Noyon (1150), the motive of the Cathedral at Spires is modified by three important changes; a gallery is first arranged above the side aisles, above this being an internal triforium gallery, then first is the hexapartite vault introduced and all arches are pointed (Fig. 382; Lubke, p-358,395,396; V-l-Duc, IX-249). The hexapartite vault was frequently imitated in Germany, especially on the Rhine, and was also a favorite in France, being used even in smaller buildings having side aisles with a single bay, as in the Church at Nesle.

Galleries and triforiums were already common in France in Romanesque; in the beginning of the 13 century, the triforium sometimes had another purpose, not merely serving to lighten walls enclosing roofs of the side aisles and to form an internal passage, but at the same time also providing an external passage above them, as at Notre Dame at Dijon (V-l-Duc, IV-132,134,135), and at S. Leu-d'-Esserent (V-l-Duc, IX-281,282). This form of triforium was commonly retained in the larger cathedrals and was frequently imitated in Germany, windows being opened in the external wall of the triforium, if no roof was outside it. A peculiar kind of inner passage, not a triforium, extending around at the springing of the vaults and behind the vault ribs and wall arches, is found in the Abbey Church at S. Seine (V-l-Duc, IX-301), beginning of 13 century, and others occur in the Cathedrals at Lincoln and Wetzlar. The triforium is generally covered by a stone slab as ceiling or a tunnel vault. Galleries are arranged to add space and are rarer in Gothic, yet were used in the Cathedrals at Paris,

Soissons, and Alby, also in some German churches, as in the Church of S. Laurentius at Ahrweiler. But vaulted organ galleries are common in Romanesque as well as in Gothic.

To treat variations in internal appearance of the triforium more fully would exceed our limits. Ungewitter (Lehrbuch (p-498 et seq.) and Viollet-le-Duc (Art. Triforium) cover the ground fully. It is considered as a series of low windows, and therefore all the changes are made, to be described in relation to the architecture of windows. It is often reduced to simple arches without subdivisions, which support the masonry up to the beginning of the windows, as in the Cathedral at Rouen and the Church at Goes in Holland, where in the first a segmental and in the latter a cusped round arch extends from one pier to another; the triforium is elsewhere treated as merely the lower portion of the window tracery, as in many French and German buildings. If instead of shed roofs, flat roofs of stone slabs are used, the triforium becomes useless and is omitted, as at Toul, Oppenheim, and in the choir of the Cathedral at Freiburg-i-B.

Five-aisled Cathedrals.

The same system applied to five-aisled cathedrals increased the entire internal architecture to a very imposing ratio of height, as in the Cathedrals at Bourges (V-l-Duc, IX-252) with a centre aisle 131.2 ft. in height, and at Beauvais with keystones 151.5 ft. above floor; the internal architecture is divided in five stories, over the first side aisle being a triforium, above which is a second side aisle with a triforium again inserted in the clearstory wall of the middle aisle (V-l-Duc, I-187). Five-aisled designs with three different heights of aisles are rare; the usual arrangement is that with side aisles of equal height and a high middle aisle, as in the Cathedral at Cologne, the Cathedral at Paris, the choirs of the Cathedrals at Amiens, Chartres, Rheims, and in the Cathedral at Ulm. If two low side aisles be added to the three-aisled hall church, as in the choir of the Church at Zwettl, this gives a third arrangement for 5-aisled churches.

Substitution of Stained Glass for Walls.

The tendency to reduce the masses of the structural system led to complete substitution of great windows for wall surfaces, and whose dimensions had increased in consequence of a growing preference for stained glass of rich colors. The dimmed light of stained glass required windows to be as large as possible, if the lighting was to be sufficient for the interior of the church. The internal architecture of the church thus gradually changed, and was transformed into a structural system, that entirely dispensed with supporting walls, and enclosed space by sheets of stained glass, whose gleaming play of color heightened the mystery of the interior.

From the time that the oblong groin vault supplanted the square one, the treatment of the vault bays in pairs was no longer necessary and was dropped. The developed Gothic of the 13 century treated each bay of the vault separately and thereby perfected the entire system of internal construction.

Hall Churches.

A simpler form of cross section of the interior, the hall design with aisles of equal height, simplified the longitudinal section, which then scarcely differed from the cross section. The 3-aisled design with equal heights of springing for all aisles leads with wide middle aisle and narrow side aisles, as in many Westphalian buildings, to a higher centre aisle (Fig. 383), but which is badly lighted, since side clearstory windows are wanting. Conversely, the 3-aisled design with equal heights of crowns of vaults and considerable differences in their clear spans leads to an arrangement (Fig. 384), dangerous in conditions of stability. Thus for hall designs, approximately equal widths of aisles is always desirable; for the strength of the buttress only affects the side aisles. By increasing the sections of the piers, the evils of hall churches with aisles of different widths may be compensated.

Owing to spaciousness of its churches, the Italian Renaissance did not need extraordinary height of northern mediaeval churches. To shape and decorate the interiors by expedients of antique architecture was its problem, solved with the most delicate feeling for proportion in masses as well as in details. By again employing simple forms of vaults, rich opportunities were afforded for painting on the simple surfaces.

61. The Interior of Choir.

The choir usually has the same height as the middle aisle, but in smaller buildings is lower; if higher, it is almost always a later addition to an older nave. In the smaller churches, its height to apex of vault is from one and a half to two or even three times the clear span; if three times the clear span be assumed as the height, this produces very slender proportions, as adopted in great cathedrals; in the Cathedral at Beauvais, the height is nearly four times the clear span.

The internal architecture of the choir is similar to that of the bays. From a base a wall, plain or lighter by niches, extends up to the inner sill of the window; for a choir aisle, the internal walls with their base and the windows are naturally moved outward, and if chevet chapels are arranged, their internal walls form the enclosure of the interior. The base of the choir is lower than in the nave or is entirely omitted, if the choir be raised three or more steps. In French and in some German buildings (

Freiburg, Strasburg) the base in the choir is sometimes shaped as a seat. The distance of the sill moulding of the windows from floor must at least be more than the height of a man, and is even increased for the location of church furniture. Wall shafts extend down to the floor and rest on bases, or sometimes only to the sill course and are received on corbels, when the sill does not have sufficient protection.

In richer designs in Romanesque, the wall niches are sometimes developed into half-round niches, as in the Cathedral at Spires and in S. Paul at Worms, but in richer buildings of transition and Gothic styles, as beautiful arcades with small columns, as in the Cathedrals at Bamberg and Strasburg, in the S. Chapelle at Paris, etc.; they are then connected by an internal passage, as in the Cathedral at Freiburg (Ungew. Fig. 221), or are arranged on the interior of the choir, as on the Cathedral at Basle.

As for windows, the arches spanning them are generally concentric with the wall arches only when the window occupies the entire length of the bay. If this be not the case, the windows are set up as high as possible in order to most fully utilize the light from the clearstory, and the wall arches are even set much higher than the longitudinal arches separating the main and side aisles, most strikingly in Notre Dame at Paris (V-l-Duc, II-289, 290) and on the western choir of the Church of S. Katharine at Oppenheim (Beit.Taf. 51, Fig. 12). The top of the window may even extend above the principal cornice, if tracery gables be arranged above the windows, against which the main cornice abuts. What is said in regard to the choir also applies to the choir aisle, chapels, bays, and conversely.

SECTION 7. EXTERNAL ARCHITECTURE.

82. External Construction in General.

Each bay on the exterior of the church indicates a bay of the interior; instead of the triforium and gallery are external passages above the roofs of the side aisles, the whole being crowned by a great roof, which materially contributes to the external effect. Outside the internal wall piers are the vertical dividing members of the exterior, the pilasters in Romanesque, and in Gothicbuttresses and flying buttresses very effectively treat the exterior and the interior as prominent architectural members. With compact unity of the plan, the general exterior of the mediaeval church forms a rich and harmonius group, and a more complex structure can scarcely be found before mediaeval architecture. The cross form is produced in larger designs by the intersection of middle and transverse aisles, dominates the entire building, above which rise the great masses of the towers.

Cathedrals and churches with double choirs and four towers, usually with two intersection towers as at Spires, Mentz, Worms, Laach, and Hildesheim, represent one of the chief types of Romanesque groups; a second typical form of external design is seen in churches having western facades with two towers, and a third in the cross plan with one massive tower over the intersection, like many Rhenish buildings. The most complete example of a rich cathedral with six towers and an intersection tower, is German, as the Cathedral at Laon in France, also with seven towers, was never completed. To these greater works may be added an infinite number of smaller buildings, which vary the primary motive of Latin cross with its different choir endings in the most diverse ways; they extend the scope of mediaeval church architecture, always within the limits of strictly formulated laws.

The rich form of western facade with one or two towers, the porch, the gallery, the gable of the middle aisle with the great rose window and magnificent portal, contrasted with the eastern choir with square ending or apses, projecting chapels, choir aisle and chevet chapels; the richly grouped design and the system of construction of the nave, suggested in the facade and completed in the choir, assume at the intersection a unique change in the design, which characterizes and harmonizes the contrast between the nave and transepts. The Renaissance was not fortunate in the exteriors of its churches; only the smallest buildings designed were completed. The western facades usually remain unfinished, or were only completed in the Late Renaissance. The essential points in the external treatment of Renaissance churches are based on the grandeur of their effect and on their antique subdivision and decoration, then on the reduction of their roofs to the smallest possible size, so that they have little effect, and on the

treatment of the facades as ornamental parts, which do not always indicate the internal construction, as in mediaeval architecture.

83. External Construction in Detail.

Towers and Western Facade.

Romanesque towers are sometimes round, as on the Cathedral at Worms and the Church at Pfaffenschwabenheim, but are chiefly square, as also in Gothic; entirely octagonal towers are rare, but occur at Gelnhausen. The towers of the Pfarr Church at Stey are hexagonal, as well as those of the great Church at Haag; a tower in Pressburg is heptagonal, and another on the Capuchin Church at Wiener-Neustadt.

The oldest French Renaissance tower, at Perigueux, is entirely antique in treatment; pilasters or round piers support antique-like principal cornices, and between the upper principal stories are inserted two lower ones, the first having windows with straight lintels and gable caps, the second and third having round-arched windows with archivolts, the uppermost having pointed arches with archivolts. On the square tower stands a small circular temple, terminating in a dome like a pine cone. According to Viollet-le-Duc, this tower is of the first decade of the 11 century (V-l-Duc, III-289). The tower of the Palace of Diocletian at Spalato contains a principal motive of French Romanesque towers, the rich compound piers, the coupled windows, and the treatment of wall arcades; these towers rise in several stories and diminish upwards by bold offsets, their upper part frequently changed into octagonal form, and they are characterized by pointed gables, stone spires and luthern windows. Turrets are also found at the base of the octagonal part. The usually square and rarely round Romanesque towers in Germany consist of a series of stories above each other, whose walls are broken by single or coupled windows; the subdivision of the wall is in Germany by pilasters,connected together by a round-arched frieze beneath the belt-course. Towers of early Romanesque churches were sometimes staircase towers up the attic, rising in simple and unbroken form, then receiving a belfry with richer treatment; the lower portion was not decorated or was merely broken by small windows to light the stairs; thus on towers in Regensburg and on the western towers of the Cathedral at Wurzburg. Romanesque towers were either covered by stone spires or wooden roofs, and lead, shingles, tiles or slates, were employed as the covering material; according to the plan of tower, the spire was square, pyramidal or conical, lozenge-shaped, as on many Rhenish buildings with towers ending in gables, and lastly, octagonal pyramidal. A rare form of Romanesque tower with internal dome or cloister vault, which sometimes appears on the exterior, occurs in a group of middle Rhenish churches, the towers of the Church

of S. Paul at Worms, of the Churches at Cunterslum and Alsheim, the tower at Dittelsheim, and the towers of the old Cathedral at Wetzlar. (Beit. Taf. 30, 31, 32).

The elements of French Romanesque towers, and found on the towers at S. Leonard (V-l-Duc, III-295), Uzerches (V-l-Duc, 9998298), Limoges (V-l-D, III-298), and Isomes (V-l-Duc, III-315), first occur in developed and perfected form, combined in an imposing group, in the intersection tower of the Church at Vernouillet (V-l-D, III-323,324,325); the luthern windows and angle turrets are here developed into massive canopies to flank the octagonal spire. This tower is the model for the massive cathedral towersat Chartres and Senlis, and for many smaller towers, the square changes into the octagon to support the spire. The transition from square to octagon afforded oppurtunity for adding massive canopies ending in spires, naturally made triangular (Fig. 383), as at Senlis (beg. of 13 century), or square (Fig. 385) at Chartres (1140/1170), pentagonal (Fig. 387) at S. Pere (V-l-D, III-383; 1240), or octagonal (Fig. 388), as on the Cathedral at Laon, (1225-1235; V-l-D, III-387). The primary motive of the termination of the Gothic tower was thus created. A further development occurred by treating the octagonal portion of the tower as a principal story, this being made taller than the lower square stories, as at Laon and on the Cathedral and the Church of S. Nicaise at Rheims (V-l-D, III-391); the massive angle canopies were transformed into great angle towers in one or two stories.

The motive of western facade with two towers for cathedrals has been exhaustively treated in the introductory sketch of the history of architecture. Its forms in detail will be studied according to the progress of the different parts.

Towers in Gothic.

Towers in Gothic style essentially differ from those in Romanesque since they do not merely consist of nearly similar stories placed above each other, but each story has its special purpose. Upon the base rests a substructure, partly intended for an entrance hall, partly for ringing the bells, or the stairway. This is succeeded by a second story, sometimes used as gallery and organ loft, or sometimes for the clock. The third story often serves as a belfry and the dwelling of the watchman; it usually terminates with the transition from square to octagon. The belfry is sometimes followed by a fourth story enclosed by tracery, above which rises the spire; thus on the Cathedrals at Freiburg and Strasburg. Either story may be omitted, or they serve in a different sequence the various purposes mentioned.

Horizontal subdivisions of towers, from the massive water table to base

of the octagon, are chiefly of a subordinate nature; but the commencement of the octagon and the base of the spire are separated by bold horizontal masses, moulded members, balustrades of tracery, or a series of gallets and pinnacles. The angles of the square terminate in groups of free pinnacles, which load the angles and force the thrust of the vault toward the axis of the tower. Smaller towers vary the motive in various ways by omitting some stories, by simplifying the style, or by introduction of many original ideas, not permissible in large buildings. Men were least inclined to sacrifice the octagonal story and the transition from the square to the octagon.

Even for square towers, always found in countries using brickwork, like Holland, the wooden spire was made octagonal on a square base. The stone spire was closed at first, but with a general reduction of architectural masses it was made open and consisted of the richest tracery, a mode of treatment scarcely found in France, but not rare in Germany and at its climax in the towers of the Cathedral at Cologne.

The treatment of Romanesque towers in detail presents few special motives, peculiar to Romanesque and not likewise employed in Gothic, few not treated with the usual forms of church architecture. What applies to windows, string-courses and cornices, columns and piers, vaults and buttresses, also applies to Romanesque towers. But the towers in the Gothic style exhibit many peculiar motives to them.

84. Forms of Towers in Detail.

Proceeding to details of treatment of towers in Gothic, the forms of the different stories and their connection with each other first come under consideration.

Uses of Different Stories.

The lowest story generally serves as a vestibule, and its height is usually equal to that of the side aisles; hall churches are divided in two stories by a gallery, as in the Church of S. Elisabeth at Marburg, and the height of the gallery fixes the height of the lowest story. The two lowest stories together correspond to the height of the middle aisle or that of principal cornice; these proportions naturally result from the communication of all parts of the building with each other by galleries, passages, etc. The second story is generally an organ gallery and may be entirely omitted, if the tower is entirely included within the body of the church; the gallery and triforium usually extend around the tower externally or internally and across the west facade, forming a proper expedient for contrasting the horizontal with the verticalism of the architecture; Notre Dame at Paris and the Cathedrals at Rheims and Amiens carry out these ideas

in the grandest way. The third story is treated as a belfry and must be highest from the ground, and for the better dispersion of sound on all sides, it must rise high above the roof of the church; if this roof be very high, a story is usually inserted between the second and third to avoid excessive height of the third story, and this may be made very low in proportion to the others, as on Notre Dame at Paris, or it may attain a considerable height and even become a third story, as on the Cathedrals at Cologne and at Strasburg.

The windows correspond to the importance of the stories and are largest in the belfry as openings for sound; in Early Gothic, they are treated as groups of two or three windows with tracery in the best period of the style. If a subordinate story is to be separated from the belfry by a horizontal member for the clock or for the dwelling of a watchman, as on the Cathedral at Freiburg, this will only be by a slight indication of the horizontal on the exterior, and windows and tracery will extend through the entire story. An increase in number of stories of the tower would directly result from arrangement of galleries over side aisles, but one merely apparent may be produced by horizontal members on the exterior, as on the lower part of the towers at Marburg and Freiburg, partly to make the belfry appear larger, partly to diminish the tower by offsets in the masonry.

Horizontal terminations of towers, as in many French and English Buildings, were not intended in larger buildings, but are only found on unfinished towers. The top story terminates buttresses in groups of pinnacles, and alsothe angle turrets, one of which and sometimes all four, are staircase towers, as on the Cathedral at Strasburg. If angle turrets are wanting, a single staircase is added to the tower, if ascent be not afforded by wooden stairs inside the tower. These staircase towers may be arranged as previously mentioned (Fig. 305), but are joined to the sides of the tower (Fig. 389), as in many Dutch towers, and end as required by esthetic reasons in short or long spires, which increase the effect of the spire of the tower. These small spires are of stone or of wood, same as the main spire of the tower. Windows are either spanned by arches beneath the main cornice, or extend above the main cornice of the tower and then have gables, intersecting the main cornice and joining with the galleries and angle pinnacles to form the crown of the tower. Details of these gables will be described under the architecture of windows.

Stone Spires.

A stone spire may be produced by triangular walls equal in number to its sides, holding each other in equilibrium; if perforated, then are they many struts connected at their ends and in equilibrium. The steeper the sides

of the spire the less their thrust. The spire may be more easily overthrown by the wind, the lighter its material and the larger the surface presented to the wind. Thus stone are preferable to wooden spires, and perforated are better than solid spires, or perforated spires may be carried higher than if solid, for equal dimensions of base. Spires either stand with sides parallel (Fig. 390) or diagonal (Fig. 391) to the sides of plan of top story of tower; for square towers with octagonal spires there are the commonly employed normal forms (Figs. 392, 393), and for octagonal towers the arrangements as shown. (Figs. 394, 395).

For conical spires and those of slightly curved outline (Fig. 396) joints of the different courses are generally made normal (Trepta in Hesse; Ungew. Fig. 832), but for straight spires they are made horizontal, so that the spire acts like a system of corbels; this construction is preferable and admits of more simple jointing. The upper part of the stone spire ends in a knob (Fig. 397), naturally wrought in one piece with the upper end of the spire, and in perfected Gothic it is shaped like a cross-flower, as for pinnacles, rarely as a stone cross or statues; if the spire be very large, its upper end is constructed of several courses of stone.

Spires for towers are models for spires of pinnacles, and what has been said in regard the latter applies to the former; French spires are usually ornamented by tile-like patterns, but German spires are chiefly plain; angles of spires are usually decorated by crockets. On French cathedral towers slit-like openings or holes are usually made in walls of spires, while on German towers these are entirely replaced by tracery; forms of tracery are then arranged that horizontal connections may be supported at their centres if required, and their heights may be equal (Fig. 398), as on the Cathedral at Freiberg, or may diminish in proportion to the inclination of surface of spire (Fig. 399), as on the Cathedral at Cologne. The tracery is arranged to suit the construction of the spire, whether for octagonal spires (Fig. 400, upper half) each course be composed of eight stone slabs alternately bonded together, or for large spires each course and side be formed of several slabs (Fig. 400, lower half). Very large spires are best constructed with eight ribs with radial joints arranged on plan (Fig. 401), against which are set the slabs, externally jointed normal to the surface, internally towards the centre. By iron anchors or by projections cut on the stones of the upper course to enter holes in the lower course, the separate rings of the spire are held together firmly, with other iron anchors, cramps, and stone dwells. Angle crockets of the spire are wrought on the different courses (Fig. 402) or as separate pieces inserted in openings.

Luthern windows in spires of the better period are rare, but do occur,

as on the Liebfrauen Churchs at Works; a vertical intermediate part with windows is sometimes at the middle part of the spire, made accessible by a staircase in the spire, and may be corbelled out from the surface of the spire. This intermediate story in the spire itself, is sometimes only treated as a strongly projecting balcony, as on the Cathedral at Strasburg and the Frauen Church at Esslingen.

On the spire of the tower of the Cathedral at Strasburg, the eight ribs of the spire each support six small spires connected together, which give access to the balcony (V-1-D, V-439). The eight ribs of the spire can stand separately and only require to be connected together at the apex, as proved by the ugly but interesting spire of the Church at Langendenzlingen in the Bavarian highlands, a demonstration of the stability of perforated spires executed in stone. Instead of angle crockets, the late mediaeval period sometimes used foiled arches with tracery forms extending along the angles of the spire, or replaced crockets by pinnacles, as on a staircase tower on the south side of the Cathedral at Strasburg.

Wooden Spires.

The proportions of wooden spires are given by wood construction, and their forms are substantially similar to those of stone spires. If the tower be square, these spires are octagonal and change from the square at their bases (Figs. 405, 406); the octagon may be set diagonally (Fig. 402) or parallel to sides of the square (Fig. 404); if the square tower terminates with gables, this naturally produces the two most commonly employed forms of octagonal roofs combined with gables, as in Figs. 390, 391, 392, 393. In another form, the base of the spire is the intersection of the octagonal pyramid by a broach, (Figs. 405, 406), and the spire may be flanked by four smaller spires (Fig. 407); these smaller spires are usually treated as square (Fig. 408) or polygonal angle turrets, connected by a balustrade and corbelled out like a corner bay. Octagonal towers terminate in spires of the same form, arranged with or without gables. Luthern windows are desirable for wooden spires for making repairs, and are placed at base or apex of spire or between these points. For wooden spires, the construction further permits vertical intermediate stories with or without balcony and balustrades. Decoration of wooden spires by crockets and crossflowers, crosses, gargoyles, balustrades, etc. remains similar to that of stone spires, but the decorations are made of lead or copper. A most peculiar tower is that at Schwatz in the Tyrol (Fig. 410).

Roof Spires.

Roof spires are small wooden spires towers under the same rules as wooden spires; on them was lavished the feeling of the mediaeval architect for

form, and they are sometimes developed into architectural masterpieces, as on Notre Dame at Paris and on the Cathedral at Amiens (V-1-D, V-459, 470).

Transition from Square to Octagon.

An important characteristic of mediaeval bell-towers is the treatment of transition from square to octagon. This transition is effected in the interior of the tower in the most varied ways, and was also executed by different methods in Romanesque. Corbelling was simplest, as on the Cathedral at Wurzburg (Fig. 411; Beit. Taf. 33, Fig. 5), or the pendentive with a partial tunnel vault (Fig. 412), as on the Church at Nantau in France (V-1-D, VII-110) and on the Liebfrauen Church at Oberwessel (Beit.Taf.34, Fig. 1). A peculiar corbelling is shown by the dome over the intersection of the Church at Montbron (Fig. 414; V-1-D, IV-355) and also in the pyramidal corbelling of the Church at Loches, supported by a series of projecting courses, passing from square to octagon (V-1-D, IV-366), as well as the tower of the Church of S. Burckhard at Wurzburg (Fig. 413; Beit. Taf. 32, Fig. 2), and that of the Liebfrauen Church at Wurzburg (Beit.Taf. 35, Fig. 4).

A form of transition from square to octagon is common in French Romanesque, that of the spherical vault (Fig. 415) divided into several annular courses and connected with domical forms, and found on towers at Alsheim, Guntersblum, and S. Paul at Worms (Beit.Taf.30,Figs. 2,3; Taf.31, F.2).

Transition from square to octagon may also be made concentric rings, each forming a tunnel vault set diagonally, as on the tower of the Church of S. Jodocus at Landshut (Fig. 416). A peculiar solution is in the vaults over the intersection of S. Arbogast at Ruffach (Beit.Taf.35, Fig. 7; Fig. 417), and in combination with spherical and conical vaults on the towers of the Church of S. Paul at Worms (Beit. Taf. 30, Fig. 6; Taf.32, Fig.5), also in a very ornamental manner over the intersection of the Church at Gelnhausen.

The favorite transition from square to octagon in German Romanesque churches is that with spherical vaults (Fig. 418), employed in Cathedrals at Spires, Worms, and Mentz. A richer treatment was given to the transition from square to octagon over intersections of Gothic cathedrals, unusually rich in the Cathedral at Herzogenbusch and in the Cathedral at Milan. The simpler transition from square to octagon on the exterior has been mentioned in the treatment of stone and wooden spires; stone spires generally require at angles of the square base of the polygonal spire heavy masses, canopies, pinnacles or angle turrets, and to be strengthened at angles by buttresses, developed into massive groups of pinnacles in large towers, as on the

Cathedral at Freiberg, tower of S. Stefan at Vienna, and on the Cathedral at Frankfurt.

Primary forms of wooden spires may also be employed for stone spires, changing the system of construction; thus small towers on the Cathedrals at Strasburg and Freiburg are treated in the same way as wooden spires. (Ungew.Fig.874). Peculiar and rich forms of transition from square to octacon are produced by arranging a short portion of the octagonal part, developed from the square base (Fig. 419; Ungew. Figs. 865, 873), and by the projection of a tower balcony beyond base of spire, then be supported by small columns standing on the edges and sides of the spire (Fig. 420; Ungew.Fig.859). Transition from square to octagon is made most complex by insertion of cross-shaped intermediate parts (Fig. 421), as on the tower of the old Cathedral at Wetzlar (Fig. 421), or of star-shaped masses of masonry (Fig. 422), as on the Cathedral at Freiburg.

85. Portals, General.

Doorways of mediaeval churches are relatively small, seldom higher than 11.48 to 18.40 ft., just sufficient for passage of processions with canopies, church banners, etc. The great thickness of walls in the lower stories of churches and towers required the portal to be widened externally, to make entrance easier; if the wall was not thick enough for such increased width, frequently demanded for esthetic reasons rather than for convenience, the portal must then be treated as a vestibule, projecting from the wall surface to suit the widening of the portal. According to the thickness of wall and dimensions of the doors, the portal naturally became more or less imposing. Jamb and soffit were recessed in rectangular offsets, as in the example from Mentz Cathedral, Figs. 423, 424, the reentrant angles were filled by small columns, continued above their capitals as plain, moulded, or decorated rounds (Fig. 424). Convex angles of the recesses remained or were cut off by mouldings, so that a splayed and effectively subdivided door jamb was finally produced. With the development of sculpture, portals of prominent monuments were ornamented by the richest decorations and figures; magnificent examples of such portals occur in Romanesque in the Schotten Church at Regensburg, the Monastery at Heilsbronn in Bavaria, the Cathedral at Bamberg, and the so-called Golden Doorway at Freiburg in Saxony. Larger portals are seldom spanned by arches without a lintel, but a stone central mullion usually divides the opening of the doorway which is covered by a horizontal lintel, the load being carried by an arch enclosing the tympanum of the doorway or the transom window.

The Gothic retained the motive for treatment of the portal, given by Romanesque, but changed the mouldings (Figs. 425,426), usually spanned the op-

ening by a pointed arch, and employed for decoration; its entire apparatus of tracery, pinnacles, gables, canopies, foliage and figures. Such masterpieces, as shown by Fig. 427 from Monastery at Ebrach, are shown by nearly all larger cathedrals and churches. Smaller doorways in Romanesque and Gothic are merely spanned by one or more concentric arches and exhibit most varied and picturesque forms, differing from the usual one (Fig.425, Cathedral at Mentz; Fig. 426, City Gate at Andernach. Figs. 425, 426, 427, are at a scale of 1 : 40).

The doorway is entirely independent in form from the rectangular leaf of the door and is generally covered by a horizontal lintel, whose span may be reduced by corbels (Fig. 428); to prevent fracture, this is sometimes very high, as on the Church at Montreal (Yonne), where it is 3.94 ft. high for clear span of 5.25 ft. (V-1-D, VII-412). If made of material easily broken, like volcanic tufa, as in many French Romanesque works and Rhenish buildings in the transition style, like the Church at Sinzig (Beit.Taf.7,Fig.10), it is made deeper at the centre and the load is carried by two voussoirs of hard stone (Fig.429). It often forms a single piece with the tympanum of the doorway, as on the Church at Niederingelheim (Beit.Taf.7,Fig.2), as well as on that of S. Martin at Colmar.

For larger spans, the lintel of the doorway is constructed of numerous stones with complex jointing, as on the portal of the Church at Villers-S-Paul (V-1-D, VII-399). It relieved of load as much as possible, by the tympanum and by a transom window, and by a peculiar arrangement of jointing above it, as on the Cathedral at Wetzlar (Beit.Taf.10,Fig.3) and on the Parish Church at Steyr (Beit.Taf.11,Fig.5), and also by discharging arches. In Gothic the stepped recesses of the jambs of the doorway sometimes entirely disappear and are replaced by splayed jambs, before which stand small columns supporting the recessed arches.

Oppurtunity for ornamentation is afforded by the rounds of the arch and its hollows; Romanesque portals employ geometrical forms as ornaments, recalling wood-carver's work, with running bands of leaves and stems, interwoven and combined with figures of animals; Gothic employs rows of graceful naturalistic leaves, garlands of leaves, and a series of figures beneath canopies. Tympanums in Romanesque and Gothic were chiefly adorned by figures, frequently in several series, sometimes covered by foliage, and treated in the most beautiful manner in Romanesque on S. Martin at Worms, and in Gothic on the Church of S. Elisabeth at Marburg, and the Cathedral at Freiburg. A rare tympanum with centre occupied by a suspended keystone is on the Cathedral at Wetzlar (Fig.430; Ungew.Fig.782). The letter Gothic frequently divides the tympanum into panels by blind tracery, with or

without figures. Between the columns of the jambs in richer designs were interposed pedestals with figures, sometimes larger than life and covered by canopies. Luxuriant Gothic also employed blind tracery on portals, wherever oppurtunity was found. The small columns of the portal stand on low pedestals, sometimes on a common base in French cathedrals, ornamented by patterns like fabrics, as on the Cathedral at Amiens (Ungew. Fig. 793), or by draperies imitated in stone, as on the Cathedral at Rheims (Ungew. Fig. 794).

The treatment of smaller portals, of which a rich collection is found in Villet-le-Duc (Arts. Porte, Porche) and in my Beiträge, admits of very varied forms, since the smaller span permits different treatment of lintel of the doorway, not always required to be straight but may be arched, so that many forms may be justifiable in smaller work, whose use must be excluded from great compositions, that these may not assume a character of littleness. Simplified construction permits many solutions impossible in great works. Thus over small doorways in ecclesiastical and secular architecture, the lintel of the doorway is sometimes cut as a pointed arch, or as two coupled round arches, like a doorway in the Cathedral at Freiburg (Beit. Taf. 7, Fig. 3), or as a trefoil arch, especially in transition and Early Gothic. Late Gothic and northern Early Renaissance, which always employs as many Gothic as Renaissance forms, obtain richer forms of lintel of the doorway by combining straight and arched forms, around which the mouldings of the jambs extend as an archivolt.

For small doors and doorways, the tympanum is entirely omitted, and according to width of doorway, strength of materials employed, and requirements to be fulfilled by the doorway, the lintel of the doorway is replaced by an arch, which may take any possible simple or compound form. The section of the jamb is composed of rounds, hollows, fillets, and chamfers; capitals at the impost are generally omitted, and rounds usually have bases and plinths like those of piers, yet mouldings more frequently stop on an inclined plane or terminate in a special ending or return, a favorite idea in Romanesque, transition and Early Gothic, and treated in the most varied manner, like roots, claws of animals, etc. The Gothic Renaissance usually shaped these endings as volutes with acanthus leaves, against which mouldings stop.

88. Gables. Read to here D er l

The western and the transept facades indicated the cross section of the building, just as the exterior of the bay is merely the converse of its interior. The principal motives for treatment of the facade are given by strengthing angles by buttresses and their loads, by towers and treatment of the

portal, by horizontal galleries, and by arranging ordinary or wheel windows. The gable then terminates the attic, which usually requires windows for light, either tall or wheel windows, or sometimes square ones.

If no windows are in the gable, it will be made lighter by internal or external recesses in the walls; but if windows exist, these are small in proportion to those of middle and side aisles, since little light is required in the attic and much in the nave. The roof gallery of middle aisle is often retained at the base of gable, so that one can pass nearly around the church at the height of main cornice. These are the governing ideas for developing the facade.

If the gable be supported by one or three great arches or has a great window, as on the Cathedral at Limburg-a-L or Notre Dame at Paris, it requires loads on its ends, which may be small towers, but do not need to extend to the ground; the gallery passages then extend through the small angle towers. The gallery is often placed in the thickness of the wall, so that the gable is merely enclosed by a thin wall next the attic, but its front surface being divided into open arcades covered by stone slabs or tunnel vaults, changed into tracery in Gothic; examples of these are on the Cathedrals at Limburg and Wetzlar, or in Gothic on the Church of S. Katharine at Oppenheim and the Cathedral at Regensburg. The recesses in the gable wall were usually replaced by semicircular niches in Rhenish Romanesque buildings, or by niches with statues in French buildings. They are ornamented by tracery in Gothic.

The gable wall of a church has a simple coping cornice; stepped or battlemented gables are rarely arranged instead, but correspond better to secular architecture. The apex of the gable is generally crowned by a cross or flower, rarely by a statue or group of figures, in Gothic style chiefly by a cross-flower. If height of gable be less than its width, as usual in Romanesque, its coping usually remains plain; but as soon as in Gothic it becomes equilateral or its height equals or exceeds its width, esthetic needs require it to have crockets, also employed on lower gables of richer Gothic buildings, but replaced in the richest by foiled arches, pinnacles or statues.

The use of gables over portals is natural, to protect decorations of the portal from rain by roofs, or to afford protection from rain to persons beneath them; the last leads to projecting the roofs of the portal more and more from the plane of the wall, sometimes extending between the buttresses, sometimes treated as a separate porch. Water is removed from shed roofs behind the gables by gargoyles, frequently employed as favorite decorations where their utility is entirely lost. Removal of weight from the portal then

led to the perforation of gables and their ornamentation by statues or tracery; the necessity of a passage above the portal and behind the gables, and accessibility of all points, which would suffer injury from weather and require repairs, led to passages behind gables, which then lost their utility and became merely decorative. Cathedrals at Amiens, Rheims, and Strasburg, afford magnificent examples of such portals with ornamental gables. Gables were retained as ornamental, even if galleries of communication behind them were omitted; ornamental gables were indispensable to richer treatment in perfected and later Gothic, also universally as merely ornamental, like the pinnacles, buttresses, tracery, and other accessories of the perfected style. This is true of architectural forms, originally structural and serving useful purposes, like columns and piers, vaults, etc., employed in the late mediaeval period as purely ornamental and for all conceivable decorative works.

Gables borrow from the western and transept gables their details, ornamental pinnacles, cross-flowers and crockets, recesses in walls, windows or wheel windows, niches with statues, foiled arches, and the like. Porches are to be considered as vaulted rooms, whose exteriors have the entire decoration of the portal; they are generally rectangular, rarely triangular, as on the Cathedrals at Regensburg and Erfurt, and are also sometimes hexagonal or octagonal. They are further single or arranged in pairs, like the beautiful porch of S. Urbain at Troyes (V-l-Duc, VII-301), or are first developed into a group of three vaults on the Church of S. Nicaise at Rheims. They are generally one story high with roof and balustrade, are covered by a terrace, or are sometimes in two stories.

87. Architecture of Windows.

The mediaeval architecture of windows results from the use of two motives, borrowed from Roman and from Early Christian architecture; the window was either regarded as an opening in the wall surrounded by a strong archivolt; the straight lintel, round, or pointed arch spanning the opening, together with the window jambs, soon developed a splay to admit the most light possible, or into rectangular recesses towards the centre of the wall, just as on the portals; the reentrant angles of the recesses were filled by rounds, angles were sometimes moulded, and imposts were decorated by smaller capitals and the lower ends by bases and plinths. The general transformation of mouldings into softer forms, already treated in the forms of piers and ribs, was carried out with the development of the vaults in Gothic also on portals and windows, as for all other moulded members of the building.

Windows in Early Christian were filled by perforated marble slabs, whose transparency somewhat increased the dim lighting of the interior. After

the rediscovery of glass staining, already known in antiquity, first employed in the middle ages in the Monastery at Tegensee, then in the Cathedral at Augsburg, windows were generally filled with glass.

Windows in Romanesque are round-arched almost without exception; those in transition style frequently have trefoil arches, and those in Gothic are preferably pointed. Square windows are very rare in Romanesque; even very small windows have lintels cut out in semicircular form. In transition or Early Gothic, ornamental blind arches are usually worked on the lintel in form of a half quatrefoil or incomplete trefoil (Fig. 431), especially on secular and monastic buildings, as on the Church of S. Matthias at Treves; in Early Gothic, these forms usually change into cusped pointed arches. Late Gothic extended its repertory of forms as much as possible, and first generally employed the straight lintel for windows. Although the Romanesque nearly monopolized the round arch, it was not excluded from Gothic style, but in earliest Gothic was in use together with the pointed arch. Late Gothic more frequently used it for the same reason as the straight lintel and often avoided the pointed arch entirely, or assigned to it only a subordinate importance, as on many Belgian and Dutch buildings.

The pointed arch belongs to the Gothic, and was never employed in Romanesque style for decoration. The transition style, especially the Rhenish, tends to use unusual forms of windows, which may be regarded as variations of trefoil forms or half wheel windows; examples are from the Cathedrals at Treves (Fig. 431 a) and at Naumburg (b), from the Church at Gladbach (c), and from Neuss (d).

88. Window Tracery.

As windows in Gothic become larger, they required division into parts seldom exceeding 3.28 ft. in width, but chiefly a little more or less than 1.64 ft. They were divided by vertical stone mullions, moulded like jambs, at top connected with the jamb mouldings by arches (Figs. 432 a, 432 b). This gave the primary idea of window tracery, later so important in Gothic, even employed as a mere decoration for surfaces. The rounds a (Fig. 432 c) of the mullion and jamb, during the entire best period of Gothic, had capitals and bases, decorated in accordance with the treatment of the piers, and these were only omitted in the late mediaeval period.

The Gothic in England liked the Tudor arch (Fig. 433 a), also found in Belgium and Holland, rarely the pointed arch with 4 centres, (Fig. 433 b), but the oval arch is common in the two last countries, (Fig. 433 c), even in early Gothic it is very rare in Germany, as well as the segmental and the elliptical arch. Late Gothic added to these forms broken and unbroken

recurved arches (Fig.433 d,e, f, g, h, i), and in Saxony and the adjacent provinces of north Germany, the so-called curtain-window arch, composed of three, four or more circular arcs convex towards the opening. (Fig.433 k, l).

One motive for filling the window without large sheets of glass, intermediate between Early Christian windows filled with marble slabs perforated by round openings and Gothic tracery windows, was very seldom employed in the middle ages; we find this motive in a window lattice of stone representing interlaced circles, on the Church at Fenêoux (V-1-D, V-271), of very moderate size, 0.89 ft. wide and about twice as high. Early Gothic employed this motive with stained glass, both inserting perforated stone slabs in the principal divisions and openings of window arches and also filling the window with a network of stone instead of tracery forms, as on the Church of S. Martin at Hallerstadt. (Fig.434; Beit.Taf.18,Figs.7,8).

Window jambs are usually moulded and without ornament; Early Gothic and transition styles sometimes decorate them by leaf-buds and flower-buds, which in perfected Gothic were only added to the discharging arch of the window (Examples from windows of towers of Cathedral at Limburg-a-L; Beit. Taf.18,Fig.2, as well as windows of Castle of S. Ulrich near Rappoltsweiler, Beit.Taf.14,Fig.1).

Coupled windows were sometimes accented in Romanesque by a rectangular enclosure, as on the Castle of Münzenburg (Beit.Taf.213,Fig.3), and on a cloister window of the Church at Aschaffenburg (Beit.Taf.13,Fig.4). The enclosing moulding was enriched by ornamental forms in the first example, and may be interrupted at the middle of the pair of windows by a semicircular discharging arch, as on towers of Catholic Church at Niederingelheim. (Fig.435; Beit.Taf.13,Fig.5). In early Gothic, triple windows are sometimes combined in one group under an enclosing arch, as on the windows of the Hall of the Castle of Münzenburg (Beit.Taf.14,Fig.3).

Hood mouldings over windows were seldom used in Romanesque, but do occur, as on Cathedral at Spires (Beit.Taf.13,Figs.1,1 a). In early French Gothic, they are usually in the form of a moulded arch, which projects from the face of the wall and encloses the window. On many Early Gothic houses in Regensburg are horizontal hood mouldings and those forming low gables, in some cases decorated by crockets and a gable flower (Beit.Taf.13, Fig.14). Late Gothic frequently employed hood mouldings for rectangular windows of secular architecture, broken in rectangular form around the corners of the windows and extending along the wall beside the window. The window sill either is straight, in connection with a drip moulding or continuous string-course, or it may be a simple splay, on which frequently rest

corbels in secular windows to receive flower pots, etc. In church windows, as in Arts. 83 and 84, the splay is usually combined with the wash of the string-course which carries the water drip.

The earliest window tracery originated in a natural way by placing a pointed arch over a pair of small windows and inserting a circle inside it; if this circle be composed of small stones (Fig. 436), as in windows of the Cathedral at Soissons (beginning of 13 century), the spaces between the ends of the arches must be filled with masonry; but if constructed of few stones, as in windows of tower of the Cathedral at Limburg (Fig.427; 1225), these spaces could be left open. The circle was in the first case subdivided by six foils (Figs.436,438) inserted in the circle by tongue and groove (Fig.439, and held together by an iron ring, to produce smaller spaces for stained glass (V-1-D, V-377; in the second case, a perforated stone slab was inserted in a circle (Beit.Taf.18,Fig.2). The first method by filling the circle with foils composed of several pieces continued as the usual one in France, and is found in fully developed window tracery in Germany about 1250 in the Cathedral at Freiburg; the cusps of the foils were then perforated, first in the choir of the Cathedral at Rheims. The second method was developed on the Cathedrals at Wetzlar and Naumburg, which retained the filling of the window circles by perforated slabs. The model for this method was doubtless afforded by the Cathedral at Chartres, whose windows already exhibited at the beginning of the 13 century the original motive of large rosettes constructed of perforated stone slabs.

The attempt to combine the circle inserted within the pointed arch with the small window arches may be best followed on the Cathedral at Wetzlar and other German buildings. About 1225 this was attempted in the windows of the choir of the Church at Wetzlar, the upper part of the circle being entirely free from the principal arch, but its lower part was combined with the pointed arches of the divisions of the window and received a common jointing (Fig. 440). The windows of the Cathedrals at Rheims had already been so constructed about 1215, but those of Wetzlar retained the local tradition of filling the circle with a perforated stone slab, and triple window tracery was even produced, the tympanum of the arch being composed of three circles filled by three perforated stone slabs (Beit.Taf.18,Fig.5). A further advance in developing window tracery consisted in combining the upper part of the circle with the enclosing arch. This was peculiar to windows of Early Gothic buildings, like the Liebfrauen Church at Treves, the Church of S. Elisabeth at Marburg, and the choir of the Church at Hirzenach, so that the circle was also jointed with the tracery in the tympanum of the window, but the rounds of the window jambs did not unite with the rounds

of the circle but ran past them (Fig. 441; Beit. Taf. 18, Fig. 1). First at the Cathedral of Amiens (about 1235) all rounds in window tracery united and formed a uniform net-work. This perfected tracery was then introduced into Germany. The round of the window mullion was rarely treated as a free column connected to the jambs as well as the mullions (Fig. 441 a), as on the choir of the Church at Hirzenach (Beit. Taf. 18, Fig. 1).

The pointed arch has very singular geometrical peculiarities, which require consideration in tracery; the simplest construction of tracery, whether in two or more divisions, is where one commences at the springing and draws the small pointed arches on the base line of the main pointed arch, filling the space between them and the principal arch by a circle (Fig. 442). It is clear that the size of the inserted circle depends on whether the pointed arches are equilateral, lancet, or depressed arches, i.e., whether the centres of the arches lie within or without their spans and on their bases. Other methods for geometrical construction of tracery are based on enlarging the enclosed circle in comparison with the other openings in the tracery. This produces two springings, a and b (Fig. 443).

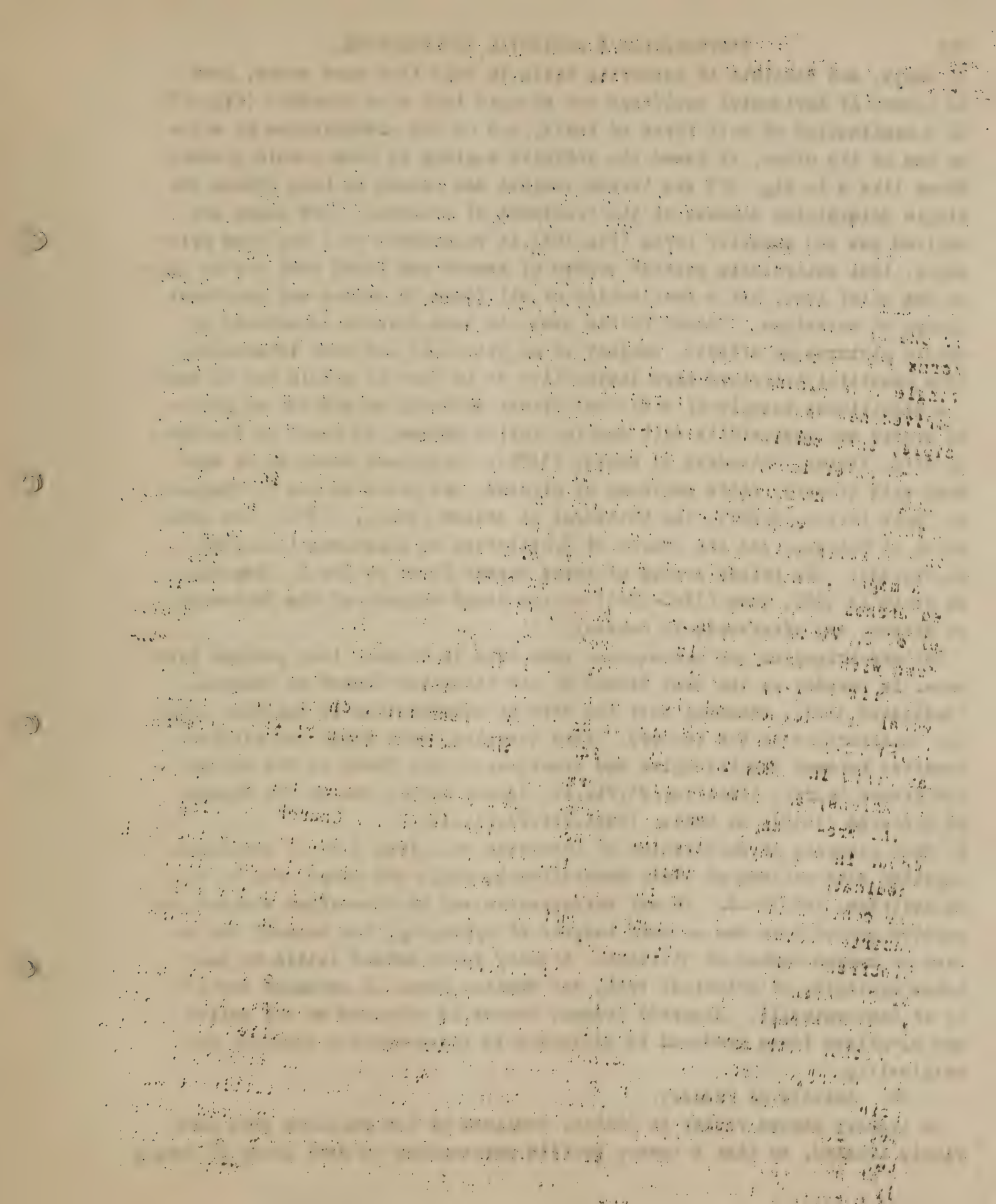
Different modes of construction are then possible, as if the circle is made tangent to the pointed arch and to its base (Fig. 444), or if a square be described on the clear span of the main arch and arcs be described from its upper corners with its side, the circle being made tangent to this arc-square (Fig. 445); lastly, by describing a complete arc-triangle to enclose the circle (Fig. 446).

Instead of the circle, and preferred by riper Gothic, the trefoil, quatrefoil (Figs. 447, 448), cinqfoil, sexfoil, etc., may be introduced; the best Gothic generally enclosed these foils by circles (Fig. 448), and like more developed early Gothic, added foils to pointed arches of the second rank (Figs. 447, 448), the cusps. Another form of tracery was created in Gothic by replacing the circle by an arc-square (Fig. 449) or an arc-triangle (Fig. 450), which in wider windows or in those with numerous divisions was soon filled by circles and foils, permitting the most varied combinations.

Window Tracery in Late Gothic.

Late Gothic increased its repertory of form by partially dropping foils and their connection with pointed arches. In tracery injured by accidents or bad construction, the entire system remains in place, although pieces have fallen (as a in Fig. 451). New forms result and are reproduced as pleasing.

Another change in forms of tracery occurs before 1288 on the Minorites Church at Cologne and soon afterwards on a side chapel of the Cathedral



at Mentz, and consists in recurving foils to make them more acute, just as rounds of horizontal mouldings are changed into ogee roundels (Fig.452). On a combination of both forms of foils, and on the predominance of either one or the other, is based the infinite variety in Late Gothic tracery. Forms like a in Fig. 451 are termed vesicas and become in Late Gothic the single determining element of the treatment of tracery. From these are derived new and peculiar forms (Fig.453) in accordance with the same principle, that subordinate pointed arches of second and third rank are no longer the chief idea, but a combination of all forms of arches and continual change of curvature. Latest Gothic uses the most diverse expedients to obtain picturesque effects, subject to no principle and more interesting than beautiful, therefore more instructive as to "how it should not be done".

A magnificent example of a window, almost entirely consisting of pointed arches and quatrefoils with doubled foiled arches, is found in the Chapel of S. Victor, Cathedral at Mentz, (1279). Prominent examples of windows with tracery, foils enclosed by circles, are found on the S. Chapelle at Paris (V-1-D, V-387), the Cathedral at Amiens (V-1-D, V-390), the Cathedral at Cologne, and the Church of S.Katharine at Oppenheim (Beit.Taf. 20,Fig.14). The foiled arches or cusps appear first on the S. Chapelle at Paris in 1230, then (1240-1245) on the choir chapels of the Cathedral at Amiens, and afterwards in Germany.

The arc-triangles and arc-squares seem rare in France; they perhaps first occur in Germany on the west window of the Minorites Church at Cologne, (dedicated 1230), assuming that the date of consecration to coincide with the construction of the tracery. Rare examples, both foils and circles inserted between arc-triangles and arc-squares, are found in the ruined Liebfrauen Church, (Beit.Taf.21,Fig.2), (about 1311), and on the Church of S.Stefan (1312), at Mentz. (Beit.Taf.21,Fig.1).

Rich examples of subdivision of traceries with from 2 to 12 divisions, together with motives of their decoration by foils and cusps, may be found in Beiträge, Taf.13-14. Normal arrangements may be classified whether the pointed arches have one or more heights of springing, the tracery has an even or uneven number of divisions, tracery forms extend little or much below springing of principal arch, and whether these be arranged centrally or non-centrally. Abnormal tracery cannot be referred to any motive and comprises forms produced by virtuosos in stone-cutting striving for originality.

89. Details of Tracery.

As tracery became richer in Gothic, sections of the mullions were more richly treated, so that a common profile corresponds to each group of larger

arches; thus the primary arch, the principal arch with its two dividing arches and the main circle, (Figs. 454, 455) have the complete profile of the smaller mullion b, and the cusp has the profile c. With the changes of mouldings during the Gothic style, there occurs a change in the profile of the mullion, so that the more costly round, produced slowly, was replaced by other mouldings (Fig. 461), or entirely omitted, to reduce the profile to its simplest possible form by avoiding fillets, as in Fig. 460. Profiles of earlier tracery are simple and plainly treated, and correspond nearly to a doubled equilateral triangle, since to resist wind pressure against the glass window, the tracing must have a greater depth than width; angles of equilateral triangles are removed to form chamfers of width about equal to the side surface of the profile, or 1/2, 1/3, or 1/4 the width of mullion. The groove for inserting the glass is formed in various ways (Figs.456,457,458), according to the adjustment of the glass, enclosed by a metal frame. In the first case (Fig.459), the metal frame is slid into the groove at a extending to b, and is then moved to the right to entirely close the opening, the joints being filled with cement that will harden.

If rounds be on the profile, the entire profile is frequently inscribed within two squares described on the common base of two equilateral triangles (Figs.460,461), whose apexes form the centres of the rounds, tangent to the squares, as on the Cathedral at Mentz. Dimensions of profiles of arches of second and third rank, as well as those of their mullions, then diminish by degrees and in earliest Gothic, so that in accordance with the filling of the openings by foils, each of these imposes its dimensions and form upon the dimensions of the profile (Figs. 462,463), as on the Cathedral at Amiens (V-1-D,VI-324,328), and on the Monastery Church at Haina (Ungew. 188), or so that each successive step of the arch or foil has the same profile (Figs. 460,461); this is both the case in the buildings of the entire best Gothic and in its last period. In g the oldest tracery, the cement is chiefly on the exterior, that the wind may press the glass against the tracery. The profiles of the tracery then usually differ externally and internally (Fig.464), as on a wheel window of the Chapel of S.Michael in the Monastery at Ebrach. The best Gothic sometimes made the profiles different outside and inside (Fig.465), as on the choir at Maulbronn. If tracery was not intended for glazing, as on the western sides of cloisters protected from weather, as at Maulbronn, or in galleries and purely ornamental works, the groove was naturally omitted.

On the geometrical arrangement of foils and foiled arches, as well as on the hardness of the building material, depends the form of the cusps. These

were earliest so treated in foils, that a broad space was left between the small inner circles, to receive an iron ring inserted in a groove (Figs. 438,462). Cusps of small pointed arches were based on the equilateral triangle, so that their apexes were also points in the circular arc (Fig.468). Cusps of foils as on portals of Cathedral at Amiens, and on windows of S. Chapelle, were decorated by beautiful clusters of leaves or lilies, as at Cologne, Mentz, Oppenheim (Beit.Taf.20,Figs.15,16,17).

The riper Gothic formed the cusps of foils on the same principle of construction as that of the smaller arches of windows, so that they were produced by intersecting circles (Figs.467,468,469); they all ended in points more or less sharp, the more blunt, the more circles composed the foil, thus less acute in the polyfoil than in the trefoil or quatrefoil. Later Gothic then combined the advantages of early and best Gothic, giving its cusps sufficient width at their ends, preferable to sharp cusps for execution in soft stone, constructing all arches on the same principle and giving to each rank of arches the same section. (Fig.470). Clusters of leaves, lilies, and ornaments were then generally omitted. Cusps were then simply so truncated, that a line joining the centres of two adjacent circular arches limited their projection (Fig.471). The coves of the cusp then intersect in a line a b (Figs.471,472). This sharp edge a b is sometimes replaced by a surface (Fig.473) passing through points a c c (Fig. 471), or the edge by the chamfer d d (Fig.474). Another favorite cusp in Late Gothic is that cut off rectangular at the point (Fig.475); a small square is then placed before the point b, which the circular arc of the foil intersects in c' c' (Figs. 475,476). Dotted lines in Fig.476 indicate the form of cusps on the foils of the flying buttresses of the Church of S. Barbara at Kuttenberg in Bohemia.

Points c' c' may also be connected with the point of the cusp by surfaces, so that the rectangular cusp appears more acute on the front in perspective (Fig.477). Later Gothic developed the cusp decoratively; an example from the window of a dwelling in Tours (Fig.478) has the square fillets of the moulding intersect; others are found on the chancel of the Cathedral of S. Stefan at Vienna, on gables of the Tower at Frankfurt-a-M, on a portal of the Church at Goss in Stieirmark, etc. The width of the truncated cusps depends entirely on the material; generally made as small as possible, and on the Cathedral at Mentz in hard red sandstone, it is not over 1/10 inch wide.

If in restorations a strong material is to be replaced by weaker and the cusps cannot be made as small as before, we should not depart from its system of construction and truncate the cusps on the triangle a' b' c' in-

stead of on the former triangle a b c (Fig.479), but must make the circles somewhat smaller than before, (Fig.479,right) a point to be carefully remembered, since the treatment of the cusp is of decisive importance to a knowledge of the relations of different monuments. A second and neglected point is that centres of cusps off simple pointed arches are always located on diagonals of the equilateral triangle (Fig.470) and not on the base of the triangle.

90. Jointing of Tracery.

An important point in window tracery is the jointing of the separate stones. A general law is that the principal arch must always remain in equilibrium and all its joints must be drawn radially. It is advisable for the jointing to be made normal to the circles of the foils (Fig.470). For economy, make the fewest points possible within the limits of the material, since each separate piece of the tracery is cut from a rectangular ashlar, and many joints require many ashlars. It if necessary to finish the closing stone of the tracery after the others have been set, since with best intention and most careful work, absolutely accurate fitting of the tracery to the enclosing arch is scarcely to be attained. The stone-cutter cuts straight joints more easily than curved ones; he will more conveniently make joints as on the left half of Fig. 480, than as on the right side of the arc-triangle. If these rules are obeyed, practice will make it easy to devise a suitable jointing. The early and the best Gothic always designed tracery with reference to jointing; later and latext Gothic frequently sinned against all laws; its virtuosity could make possible the apparently impossible, even at the cost of the rational.

Designing of a normal tracery proceeds by first drawing centre lines of the rounds or of the centre profile in general (Fig.470); in good tracery the law applies, that the pointed arch should not be made more acute than the equilateral arc-triangle. Then the width of the section is laid off from the centre line. If the tracery be further subdivided, the centre lines of the sections of second rank are drawn in the same manner and are again enclosed by the width of section of the second rank; the same process is repeated with tracery still further subdivided. The arcs of the cusps are then drawn, their centre lines laid off, and their width given. Lastly, the tracery lines are filled in, or the actual lines on the elevation according to the profiles, where it is to be remembered, that one should always proceed from the inside to the outside, drawing the cusps first, then the smaller and later the larger arches.

For the esthetic effect of tracery, it is to be remembered, that earlier Gothic properly laid no special stress on uniformity of height of all spring-

ing points, but merely endeavored to have the foils produce the greatest effect possible, and in rich polypartite tracery to accent the centre apex of the arc-triangle by the arrangement of the filling forms. Earlier tracery is effective by its grand and plain treatment. The filling forms afford a means of making the upper part of the window as large as desired by lowering the springing points of their pointed arches, and to obtain suitable spaces for stained glass.

91. Wheel and Rose Windows.

A most prominent peculiarity of mediaeval architecture is the wheel or rose window, chiefly used for lighting middle and transverse aisles, arranged in gables to light the attic; like window tracery, it is constructed and decorated on two principles; either a combination of stone slabs perforated by geometrically arranged openings (Figs.481,482), as on the Cathedrals at Chartres, Bamberg, and Lausanne, Monastery at Ebrach (Fig. 481), Cathedral at Limburg-a-L (Fig.482), or it is constructed like tracery with small columns or mullions radiating from a hub (Figs.486,487), the radials being connected by simple arches in Romanesque (Fig.487), or by tracery in Gothic (Fig.486). These rose windows indicate the entire history of mediaeval architecture in their mouldings and their forms of arches and ornaments. In French, German and Italian cathedrals, a rose window frequently occupies the entire width of the centre aisle and is the most important decorative part of the entire architectural system.

The oldest rose windows in France were those of the former triforium in Notre Dame at Paris (1165-1170; V-1-D, VIII-41); they are to be termed entirely Gothic, while in Germany before 1250 wheel windows remained Romanesque; afterwards we find an early Gothic rose window in the Church of S. Ulrich at Regensburg (Beit.Taf.2,Fig.3),almost identical in form with that executed before 1220 for the west facade of the Cathedral at Nantes; the magnificent rose window in the south transept of Notre Dame at Paris was completed about the same time, (1257; V-1-D,VIII-51), exhibits the Gothic style at its highest point, and was first imitated in Germany more than 20 years later in the equally magnificent rose window of the west facade of Strasburg Cathedral. From this is derived the beautiful rose window at Weissenburg in Alsace (Fig.486). Even German Romanesque wheel windows are already filled with perforated slabs of stone (Fig.481), sometimes treated ornamentally, as in several Thuringian churches (Beit.Taf.2,Figs.3,4, 5,6), or they were actual wheels with spokes replaced by columns connected by round arches outside and abutting against a hub at the centre; thus the beautiful wheel windows on the Cathedrals at Worms (Fig.487) and Mentz (Beit.Taf.1,Fig.1), and on the transept of the Cathedral at Freiburg (Beit.

Taf.2,Fig.1); in the transition and in early Gothic, the rose window sometimes consists only of a series of foiled arches connected by an iron cross, as on the eastern transepts of the Cathedral at Mentz (Beit.Taf.1,Fig.3), the Church of S. Paul at Worms (Beit.Taf.3,Fig.1), and on S.Michael's Chapel in the Monastery at Ebrach (Figs.483,484); sometimes composed of a series of tangent arches grouped around a central circle (Fig.482), as on the Cathedral at Limburg-a-L. In the first case, such rose windows are to be regarded as great polyfoils whose motive may vary in them, a series of concentric polyfoils being arranged (Fig.484), as on the Church at Montreal (V-1-D, VIII-65), or it may be combined with circles, trefoils, or quatrefoils, be composed of stone slabs, as at Chartres, Bamberg, Lausanne, and Gelnhausen (Fig.481), then permitting the moulding of the enclosing archivolt to take the form of the foil (Fig.485), as on the Church at Royat and on S.Stephen at Vienna.

From combination of foils and radial divisions result all variations executed in French cathedrals and German buildings. Two arrangements of radial divisions are in use, one with connecting arches turned towards the centre, the other having them turned towards the circumference of the circle; about 1800 appear first on S. Nicaise at Rheims connecting arches alternately turned inward and outward, with a tendency to oblique position or a rotation of the rose window about its centre. This afforded the primary vesica pattern, common in France and rarer in Germany, which fixed the nature of the so-called flamboyant late French Gothic, and was first used in the rose window of the S.Chapelle in the 15century. Small openings were sometimes closed by a perforated slab of stone (Fig.488),as at Hassfurth. The late mediaeval period in Germany generally divided rose windows into foils, sometimes combined with vesica forms, sometimes with segmental arches, which intersect complete circles or foils (A rich collection of rose windows is found in Beitrage,Taf.1 to 8; V-1-D, Art. Rose; Ungew.).

92. Window Gables.

The perfected Gothic often placed gables above windows, which may have originally had the purpose of loading wall arches of the vault and of ensuring its apex against movement by the thrust of the vaults, but was preferably employed later for its ornamental effect. These gables were decorated by ornamental motives like the great gables of the church, by crossflowers, crockets, by figures and tracery, were perforated or solid, or flanked by pinnacles. They usually intersect the main cornice and are combined with it in various ways.

In Art. Gable, Viollet-le-Duc ascribes the origin of the gable to a tradition, which stated a liking for the temporary wooden roofs placed

over completed vaults, while the upper walls of the church remained unfinished for lack of money, and that similar roofs were constructed of stone; this conflicts with his explanation of the window gable as loading wall arches, given in Art. Construction. Pierre de Montereau first employed these gabels in 1245 on the S. Chapelle. The true explanation of the window gable is perhaps that it was introduced to make the apex of the window as high as possible, regardless of the main cornice. The window arch might then extend to the main cornice or even above it, and the gable was built in front of the main cornice and partly concealed it, producing a general form, satisfactory both structurally and esthetically. The pointed window arch or wall arch was loaded by it at its crown, and the line of pressure was forced towards the vertical axis of the buttress by increasing the vertical load, the balustrades of the galleries were firmly fixed and their length diminished; for esthetic reasons a large mass over the window arch was only desirable, when it distinctly asserts the general vertical tendency of the building. The gables of portals had the same purpose as those of windows; they were employed as common ornamental parts wherever they had a purpose. Their construction and connection with the main cornice and galleries admits innumerable solutions, all returning to the primary idea, that they are thin walls of stone, to be connected as strongly as possible with the wall by bond stones, balustrades of galleries, etc.

93. Cornices, Belts, and String-courses.

The horizontal bands in Romanesque and the Gothic, base-courses, main cornices and string-courses, annular mouldings, astragals and base mouldings, sections of archivolts of windows and doorways, gable-copings of buttresses and flying buttresses, pinnacles and canopies, etc., are subject to the same changes, through which the style passed. As a primary law for the entire treatment of horizontal bands in the middle ages, their forms and proportions depend on the purpose they serve, on the material in which they are executed, and on their position with reference to the observer.

The material fixes the absolute sizes of mouldings; the normal height of course of the stone limits the greatest height of the member or of its subdivisions, the strength of the material decides its projection and as the minimum limit of delicacy of its forms, and the lighting and the position of the member with reference to the eye influences these proportions.

Belt courses in the early middle ages are based on late Roman buildings, those of Early Gothic are partially based on Christian buildings in Palestine and Syria, seen by crusaders. Perfected Gothic freed itself from all historical traditions in its treatment of belt courses.

The peculiarity of mediaeval forms of cornices and belts is a preference

for rounds and hollows, connected by and with fillets. Belt courses are regarded as stronger or weaker separating or connecting members, a free or restricted ending, as enclosure of a nucleus or the bordering of an opening. Like all good architecture, the chief stress in moulded members in the middle ages was laid upon energy of effect of form and good harmony f proportions.

Base-Courses.

The base of the building is a footing projecting from face of the wall and composed of one or more courses of stone, with the idea of extending the base of the building and placing it on the foundation, of raising the structure above the ground, and of visibly separating it from the ground by a powerful horizontal member. The projection of each course of the base is made by a fillet (Fig.489 a), a square or steeper wash (b,c), a quarter round (d), a cove (e), a round and cove (f), or an inverted cornice member (g). The top of the base generally indicates the top of the internal floor. For richer bases in Romanesque and Gothic, the base at ends at top with group of mouldings derived from the profile of the Attic base, as on the Cathedral at Bamberg (Fig.480), which in the development of the style by transforming, increasing, or connecting the members, suffers the changes treated in Arts. 54 and 61, an example being given in Fig.492 from the Cathedral at Strasburg. Differing from the form of the base in the interior of the building, for that on the exterior the hollow between toruses of the Attic-like base in good examples is made low at bottom for the water to readily run off, as on the Cathedral at Meissen (Fig.493). A selection of characteristic forms of base courses of different periods is given in Beitrage, Taf.37,Figs. 1 to 12. (Ungew.14 etc.Fig.61,etc.).

Among the finest profiles of base-courses in Romanesque are those of the Church of Neumunster at Wurzburg (Fig.494). Base-courses are almost invariably plain, though sometimes decorated by a lozenge ornament, as on the former Fish Gate at Mentz (Beit.Taf.37,Fig.10). If crypt windows are arranged in choirs and do not extend above the base-course, as on the east choir of Mentz Cathedral, this is broken around the window, as on the Cathedrals at Bamberg (Fig.491) and Erfurth,(Beit.Taf.4,Fig.17), and on the Magdalen Chapel in the Cathedral at Meissen.

Main Cornices.

Principal cornices serve for various purposes. They terminate the building at top, crown it, protect the masonry from rain water, and carry a gutter for removing rain water, usually being in Gothic combined with balustrades. All these require a strong projection of the main cornice. Expedients employed by the Romanesque for obtaining a strong projection of the

upper course were in France projecting the cornice slab on corbels, In Germany the richly profiled cornice was combined with the round-arch frieze.

French Gothic sought a wide projection with less height of main cornice by strongly projecting the mouldings,or for greater heights of main cornice consisting of two or more courses, by introducing large hollows, decorated by foliage, heads and by continuous ornamental friezes. Corbel cornices are often found in Germany, directly composed after French models, as on the Abbeys at Maulbronn (Fig.495) and Ebrach (Figs.496,497), and the Cathedral at Bamberg.

The Romanesque composes the profile of its main cornice with quarter rounds, rounds, hollows, and fillets, like Fig. 498 from the Monastery at Ebrach. The hollow is here subordinate in comparison with main cornices in Gothic. Rounds and hollows are sometimes decorated by leaves, like the principal cornices of the Templar's Church at Bacharach and the Church of S. Peter at Straubing (Beit.Taf.38,Fig.1,7), or by lozenges and other specific Norman forms derived from wood carving. Recurved leaf patterns like Doric cymatiums are rare, as on the Neumunster Church at Wurzburg (Beit.Taf.38, F.3). With the development in Germany, the round-arch frieze changes into the trefoil-arch frieze and in late Gothic into the pointed-arch frieze with tracery forms, as on the parish Church at Bayreuth (Fig.499) and on the tower of the Liebfrauen Church at Bamberg, where main cornices are like lace edgings. The round-arch friezes of Romanesque buildings are not moulded, but are bordered by a moulding composed of round and cove, and are frequently decorated by ornamental panels, as on the Cathedral at Bamberg and others. (Beit.Taf.38,Figs.8,10,11).

Principal cornices of Gothic buildings in Germany and France chiefly terminate at top with a water-drip, which may take the forms shown in Fig. 218 a, b, c or e, as on the Cathedral at Regensburg (Fig.500). Rounds gradually suffer the changes described for profiles of ribs, as shown by Fig. 501 from the Church of S.Katherine at Oppenheim.

Balustrades in Romanesque consist of small columns with round arches, and have in the transition style trefoil and pointed arches, but assume in Gothic the forms of tracery, which gradually change according to the development of tracery, from severe through stiff to sportive and fanciful, as shown by Fig. 502 from the Cathedral at Regensburg, Fig. 503 from S. Peter at Heidelberg, Fig. 504 from the Church of S. Valentine at Kidrich in Rheingau, Fig. 505 from S. Martin at Landshut, and Fig. 506 from the Cathedral at Regensburg. The front of the gutter is generally decorated by the water-drip moulding. If balustrades exist, the channels lie between them and are not visible.

Belt Courses.

Belt courses in Romanesque are chiefly slabs with the lower edge beveled, or with a cove, quarter-round, or three-quarter round between hollows K(Fig.507 a, b, c, d, e). Richer string-courses are composed of mouldings as elements, shown by forms a, b, c, (Fig.508) from the tower at _unterseblum, or take the form of inverted "ttic base (Fig.509). Gothic introduces almost invariably the water-drip, as recognized in Fig.210 a, b, c, d, e. Forms also occur in early Gothic like Fig. 510 a from Heistertach, b from Hirzenbach, c from the Church of S. Nicolai at Frankfurt-a-M, and d from the Dominican Cloister at Würzburg.

Annular Mouldings.

Examples of annular mouldings are Fig. 511 from Templar's Church at Bacharach, Fig. 512 from Hirzenach, Fig. 513 from the Cathedral at Strasburg.

Profiles of Window Archivolts.

Archivolts enclosing windows consist of parts containing the groove for inserting tracery panels (the profile of the mullion in tracery) and those corresponding to the thickness of the wall, in Romanesque usually a simple splay (Fig.514 a), but in Gothic generally a great cavetto b, which in the best period was sometimes decorated by continuous ornament. The outer margin of the cavetto or splay is frequently bordered by a separate moulding, which in Romanesque is composed of rounds, hollows and fillets, and in Gothic, of bowtells and similar forms.

Profiles of Copings.

Profiles of copings of flying buttresses have already been studied, and of the rare hoods over windows and doorways, with those of gables and window gables, which in their profiles follow those of main cornices and string courses. They generally have a strong projection as members to protect the covered parts from rain water, with water-drips and large cavettos beneath in Gothic. Fig. 515 is an example of early Gothic hood moulding from the Cathedral at Regensburg, Fig. 516 in Romanesque from the Cathedral at Mentz, Fig. 517 in Late Gothic from the Cathedral at Frankfurt-a-M, and Figs. 518, 519, are two profiles of copings from window gables of All Saint's Chapel in the Cathedral at Mentz, and from the Cathedral at Regensburg.

Horizontal Members of Various Kinds.

Here is to be considered a series of horizontal members, partly resembling string-courses, partly annular mouldings. First are the profiles of horizontal stone beams, as in dwarf galleries of Romanesque churches, like Fig. 520 from the east choir of the Cathedral at Mentz, and Fig. 521 from the western tower of the Cathedral at Worms. Then are profiles of corbels, employed in diverse ways. Fig. 522 is a Gothic corbel on Strasburg Cath-

edral, Figs. 523 and 524 are Romanesque corbels beneath round-arch friezes of Churches at Pfaffenschwabenheim and Laach, Fig. 525 is a Gothic corbel profile from Cathedral at Regensburg.

Allied to corbels are terminal mouldings in Gothic, which extend around free ends of stair steps, like Fig. 526 from the Cathedral at Mentz, and Fig. 527 from the Church of S.Katharine at Oppenheim. Alsothe profile of hand rail of balustrade of a stairway in the late Gothic chancel of the Cathedral of S. Stephen in Vienna (Fig.528). Further, profiles of Romanesque impost caps of arches; Fig. 529 is from portal of tower of Obermunster Church at Regensburg, Fig. 530 is from Iron Gate at Mentz, Fig. 531 a is from Templar's Church at Bacharach, Fig. 531 b is from Church at Rocsburg in Bavaria, Fig. 532 is from nave piers of Cathedral at Worms, the profile of a pier cap from the Church of S. Nicolai at Dippoldiswalde (Fig. 533) in transition style, and Fig. 534 is from Romanesque piers in side aisles of Cathedral at Mentz. All these profiles commence at top with a band, or rarely with a quarter round (Fig. 535), like the string-course on Iron Gate at Mentz.

Profiles of neckings of cross-flowers are in early Gothic mostly bowtell profiles (Figs.536,537), sometimes curved on plan (Fig.540), or cut out (Fig.539), also rarely in foil form (Fig.538) as at Cologne. Late Gothic usually gave the necking of cross-flowers the profile of the water-drip.

In earlier and in later Gothic capitels occur, not ornamented and merely consisting of mouldings. Such moulded capitals take the form of the bell capital, like Fig. 541 from Cathedral at Regensburg, Fig. 542 from pulpit stairs in Cathedral at Mentz. Similar examples are from Church of S. Burkhard at Würzburg (Figs.543,544), which have to extend the entire thickness of the wall from the small regular piers, and show the profile of the abacus projecting more in front (Fig.544) than at sides (Fig.543).

94. Ornamentation of Romanesque Architecture.

The character of the forms of Romanesque ornamentation may be briefly characterized, that if follows late Roman and Early Christian motives derived therefrom; that the decoration employs ancient Germanic elements, transferred to architecture from clothing, ornaments, vessels, implements, and wood-carving. Peculiar ornamental interwoven plant forms occur, mixed with dragons, men, and animals (Taf.3,Fig.35; S. Cunibert,Cologne), and interwoven bands, such as occasionally are found in miniature paintings of manuscripts of the Carlovingian period and of the early Romanesque, also with antique reminiscences, which only completely died out during the development of Gothic. The Romanesque style borrowed from clothing and armor forms of net-work, chain, scale, and textile patterns, interwoven bands and cords

with very realistic treatment; from wood-carving the repitition of purely geometric forms, rounds in zizag form, chess-board patterns (Taf.4); it liked froms resembling ornamentation by pearls and precious stones (Figs. 97,98,184,187). A peculiar decoration is the so-called cloud ornament, already found in the Romanesque on the Cathedral at Autun, and sometimes in Gothic in a changed form, especially in sculptures of tympanums of doorways.

95. Ornamentation in Transition Style and in Gothic Architecture.

The naturally treated plant-forms of our northern flora were adopted in the transition style, and later controlled the ornamentation of Gothic. This plant ornamentation was executed in the best period and even in late Gothic with extraordinary grace and delicacy, with bold treatment in relief, as shown in cross-flowers and crockets (Taf.1), foliage friezes and corbels,capitals and keystones of vaults (Taf.2,3), recalling hammered metal work by its treatment; in polychromatic interiors, the realistic foliage is usually gilded, its background being strongly colored (Ungew.Taf.46; V-l-D, Arts. Sculpyure, Flore, Peinture, etc.).

Oppurtunity for such ornamentation is chiefly afforded by capitals of columns and piers, corbels, cross-flowers and crockets of pinnacles and gables, contihuous or inclined friezes and cavettos, and suspended parts ending in flowers, like foiled arches of windows and portals and cusps of early Gothic polyfoils. The ornamental elements are separately arranged in a series or are grouped. Models for naturalistic plant forms are taken from our wild plants:-- ivy, maple, grapevine, anemone, parsley, wild grape, aristolochia, asarum, and others. Rarely are foreign plants found, such as the acanthus on a keystone of the Church of S. Ulrich at Regensburg (Taf.3,Fig.28), and also a fanciful arum on the choir stalls of the Monastery of Schulpforta (Taf.3,Fig.38).

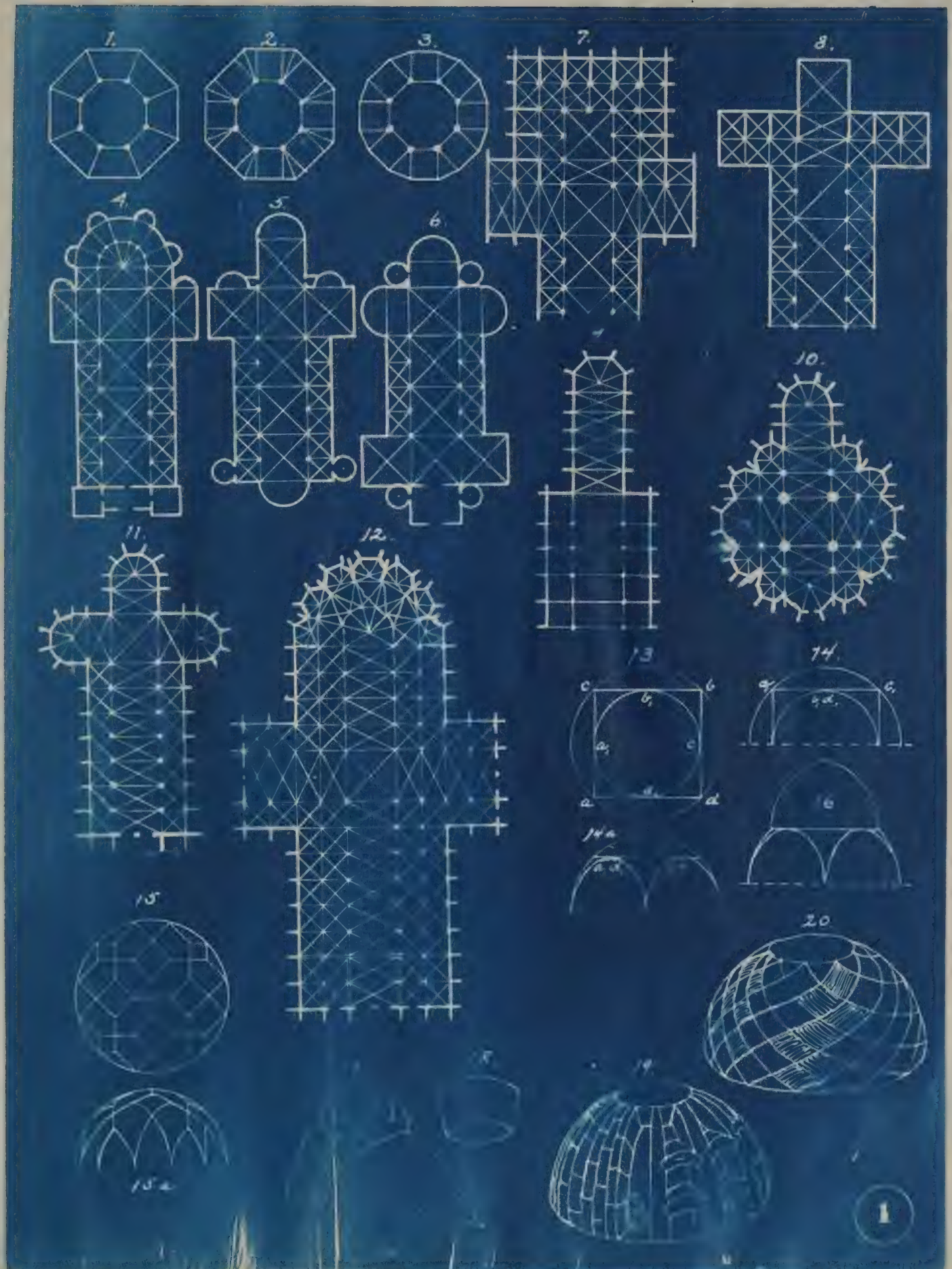
Conclusion.

In mediaeval architecture the external appearance is always based on construction, and this is its advantage over other architectural styles, which take into account merely esthetic and symbolic requirements. But the construction is often defective ; what is gained by perfecting the construction is usually lost by the use of substitutes. The best constructors in the middle ages were empirics, who knew well how to improve their system of construction, where they must give and take, always deceiving themselves in the quantity. Assuming that a loading of the masses was anywhere desirable, as on the buttress, the loading was generally either made too small or too great. To ensure the great cathedrals against wind pressure, doubled flying buttresses were employed beside each other, or even tripled

flying buttresses above each other, enclosing the building like a scaffolding and appearing to crush it. To support the vaults, they introduced the pier with free small shafts, which had no loads.

Defects in construction thus retained the same or similar evils, to those for which the Antique and Renaissance were reproached, especially that structural parts were employed where they could, or were required to fulfil no structural purpose. But the idea of making construction the beginning point of decoration was thoroughly fruitful, though structural parts should not themselves be used as ornaments, as late Gothic did in its purely ornamental works. If new paths are ever laid out in architecture, this will be largely due to mediaeval architecture. Without a thorough study of this, we lack a scale with which the Antique and Renaissance should be measured. It is to be hoped that the time is not too far distant, when the pedagogical value of the study of mediaeval architecture may be generally recognized, and may this book contribute thereto according to its worth.

The End.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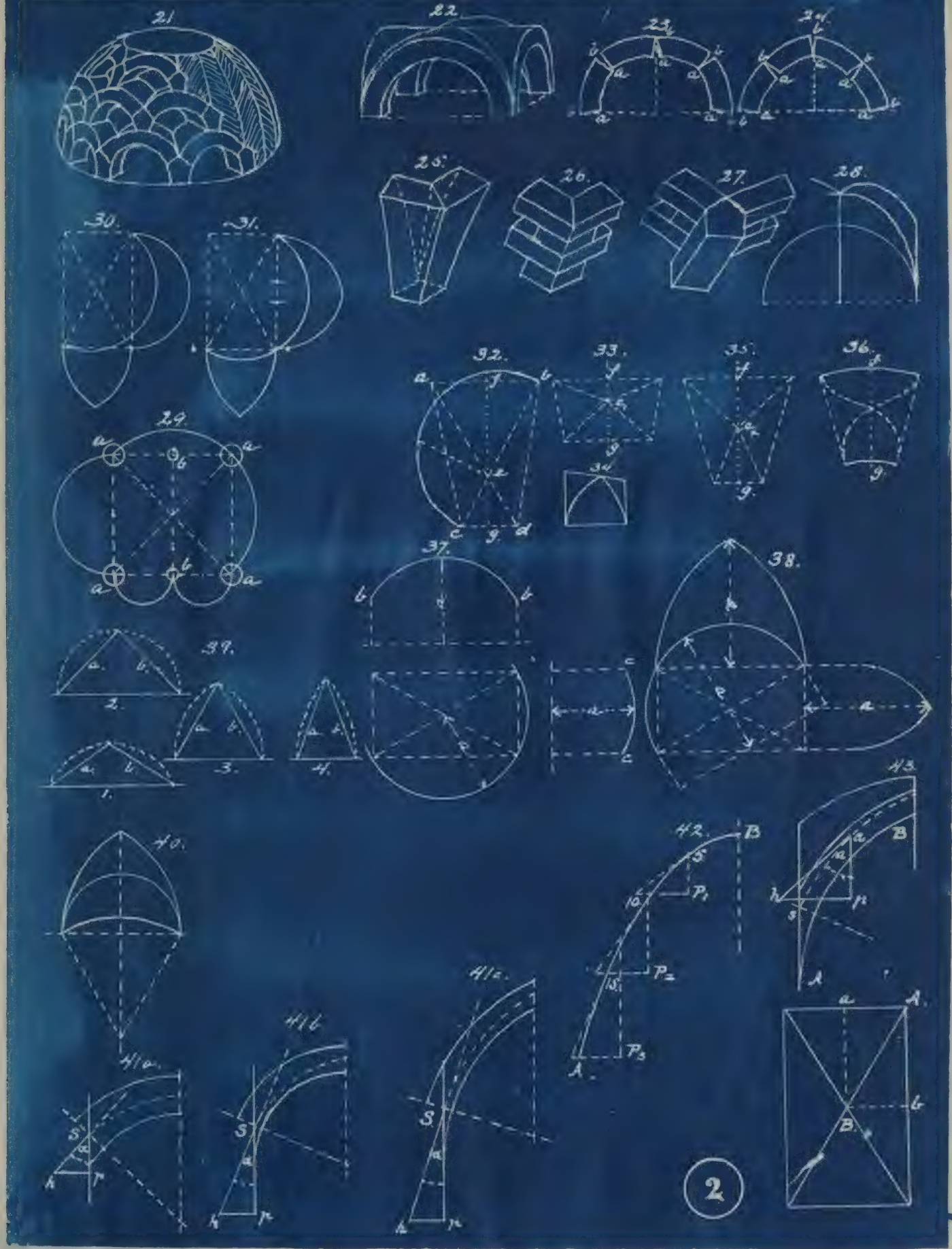
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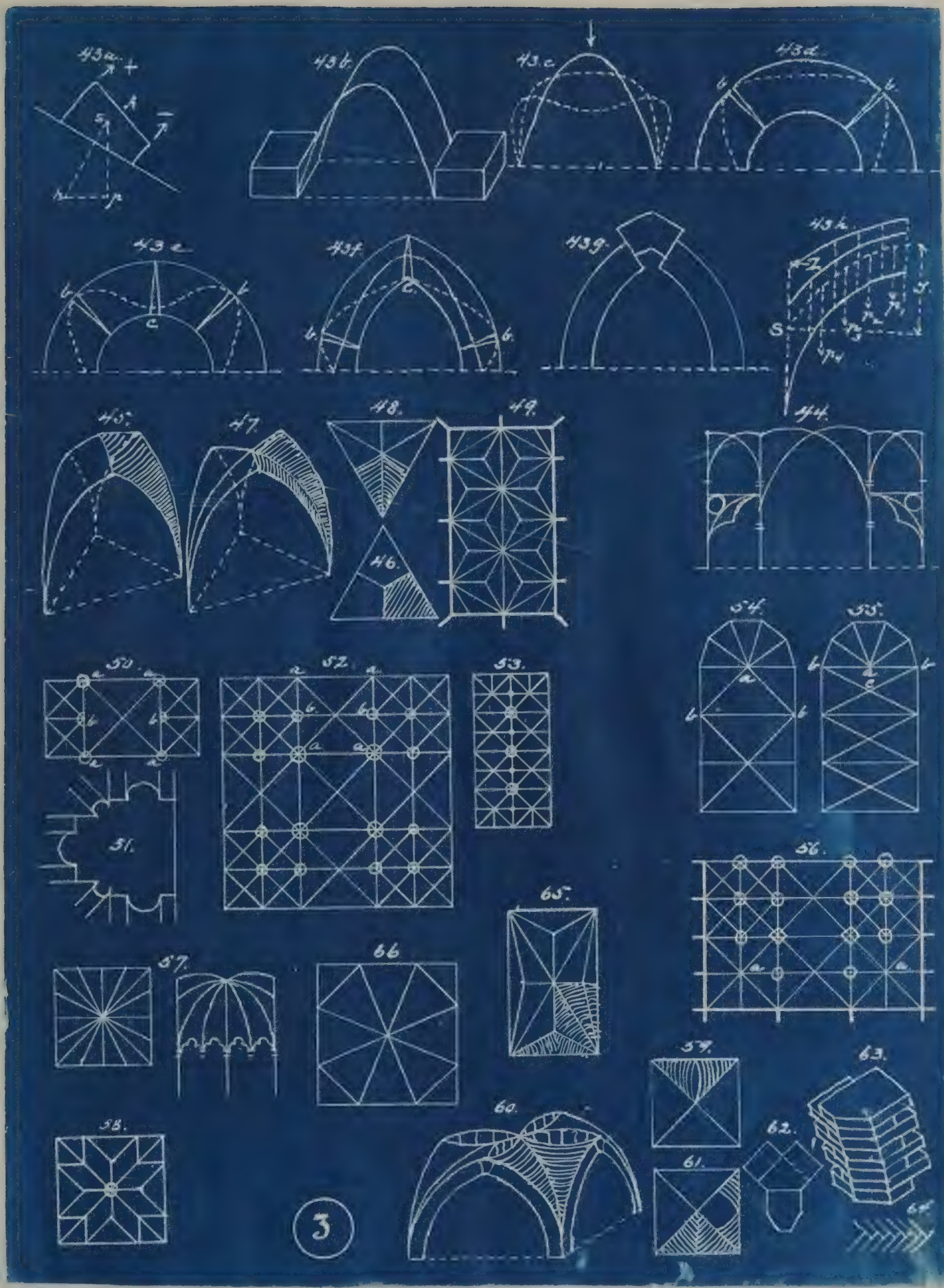
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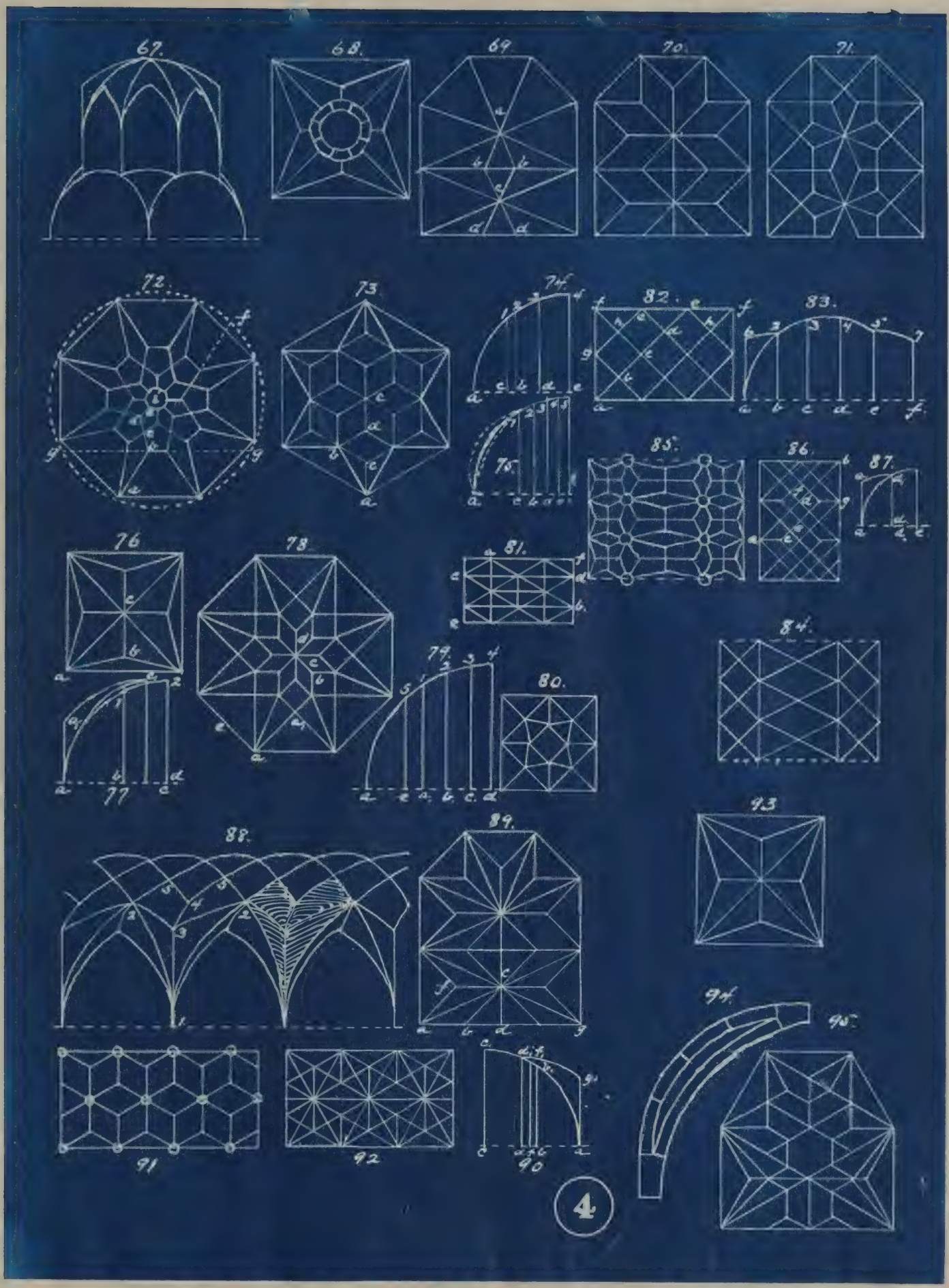
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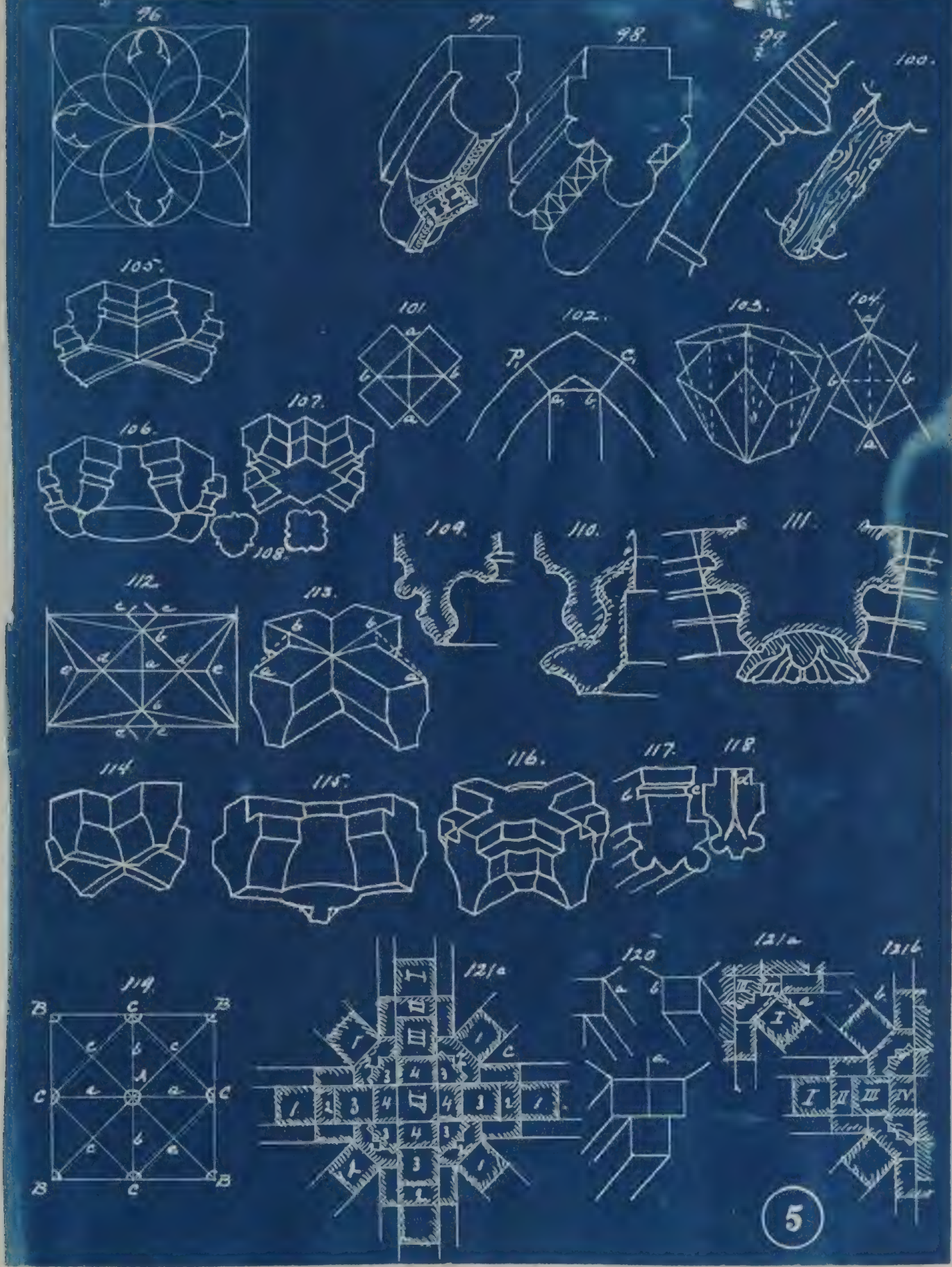
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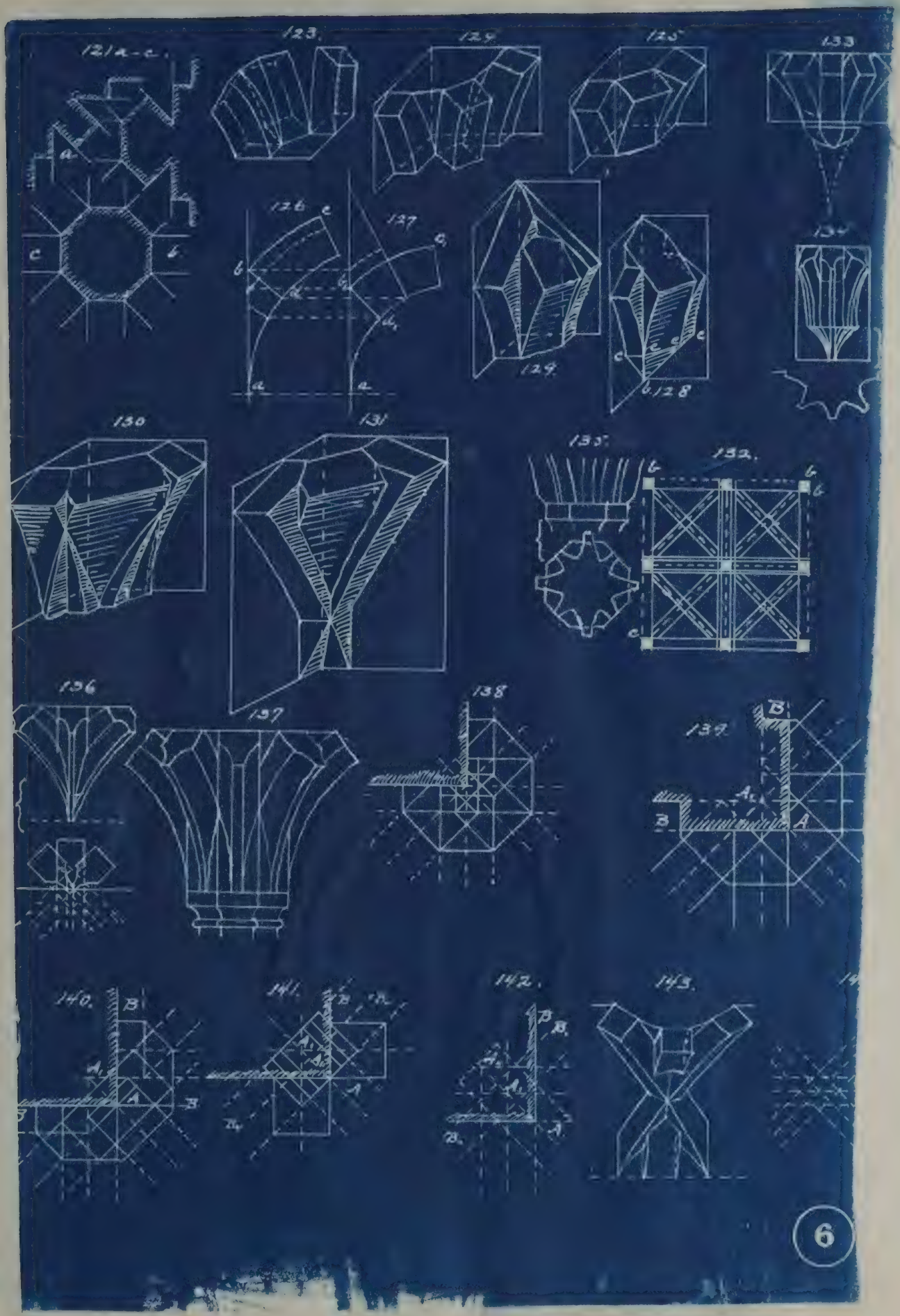
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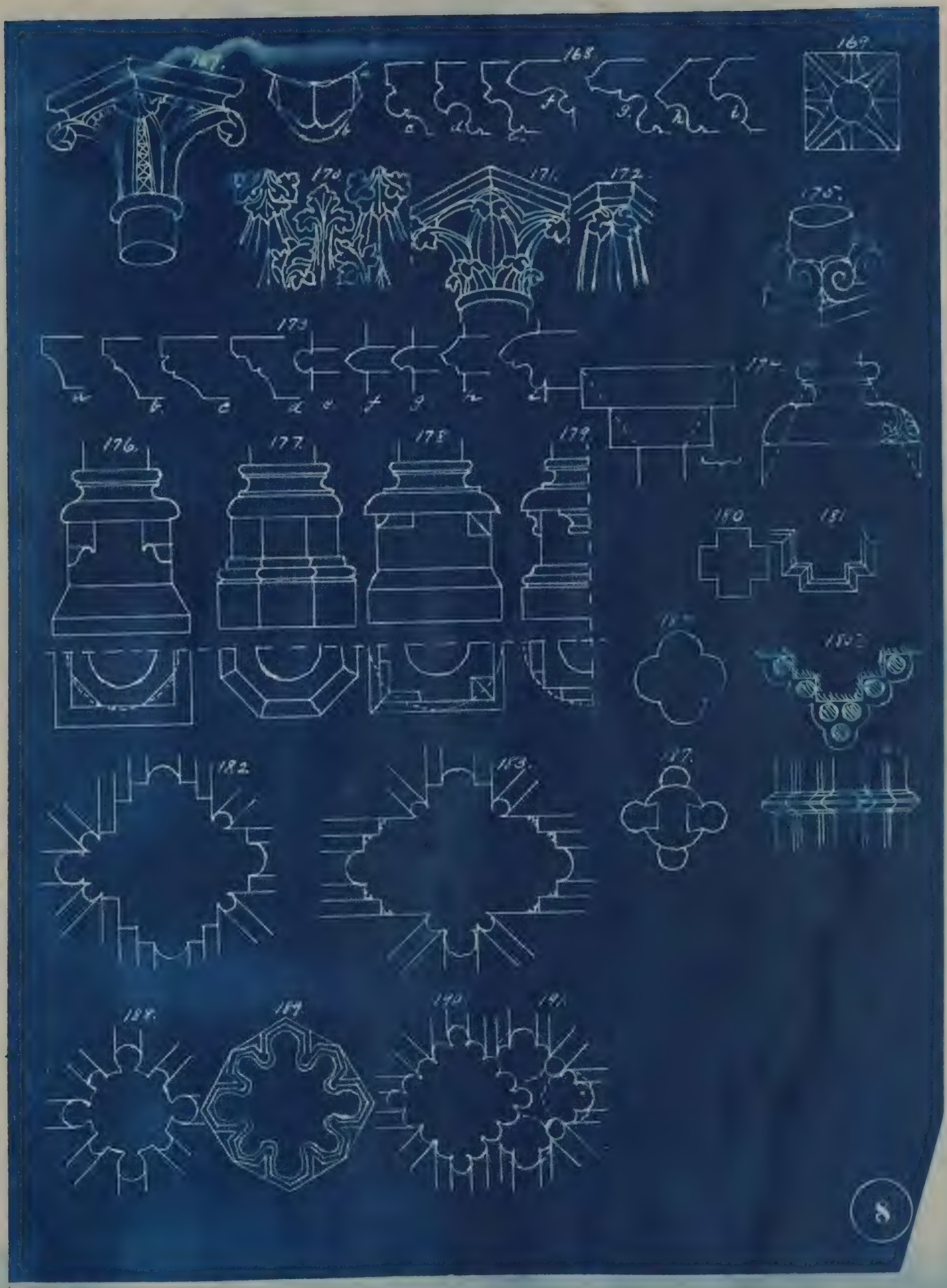
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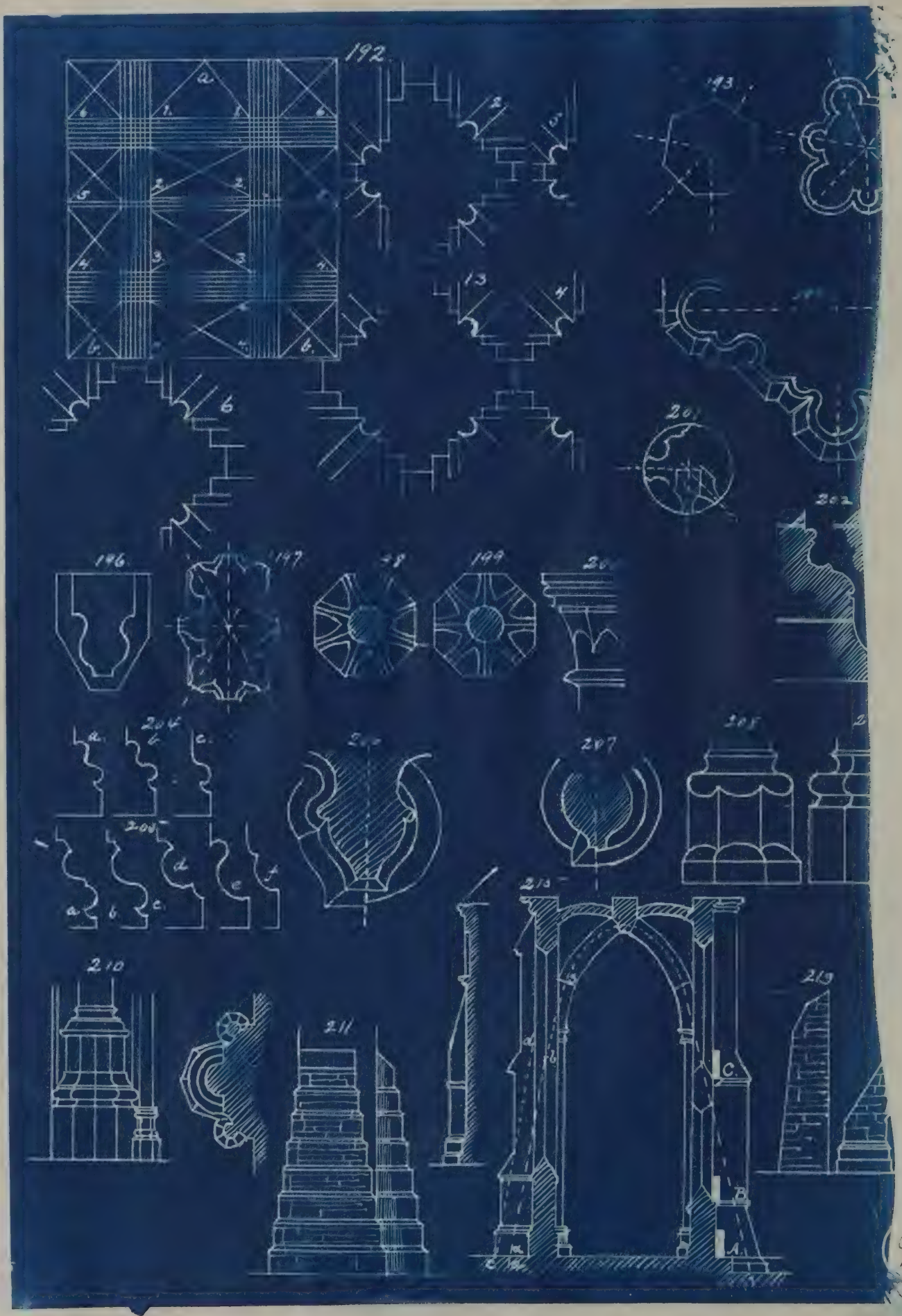
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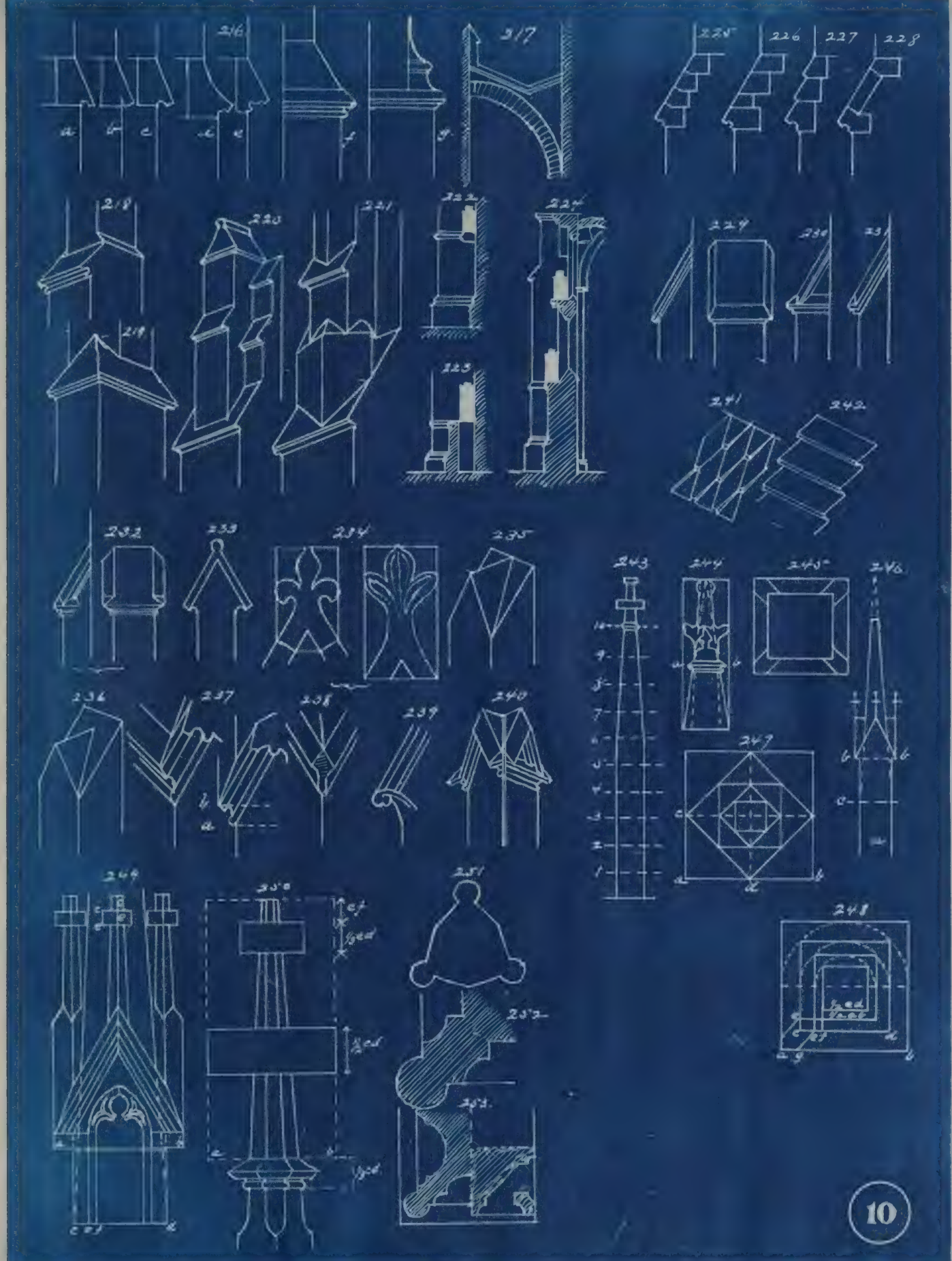
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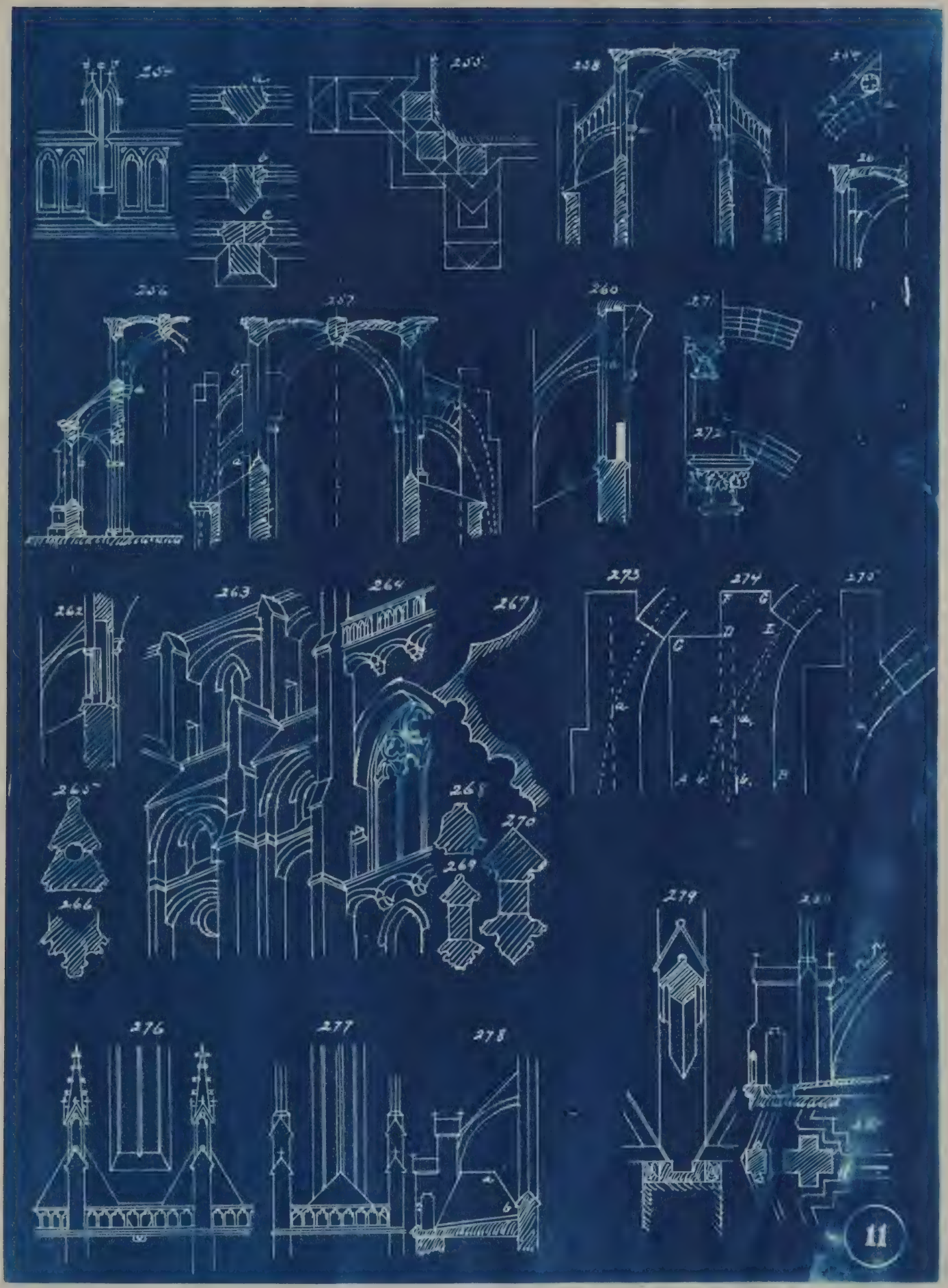
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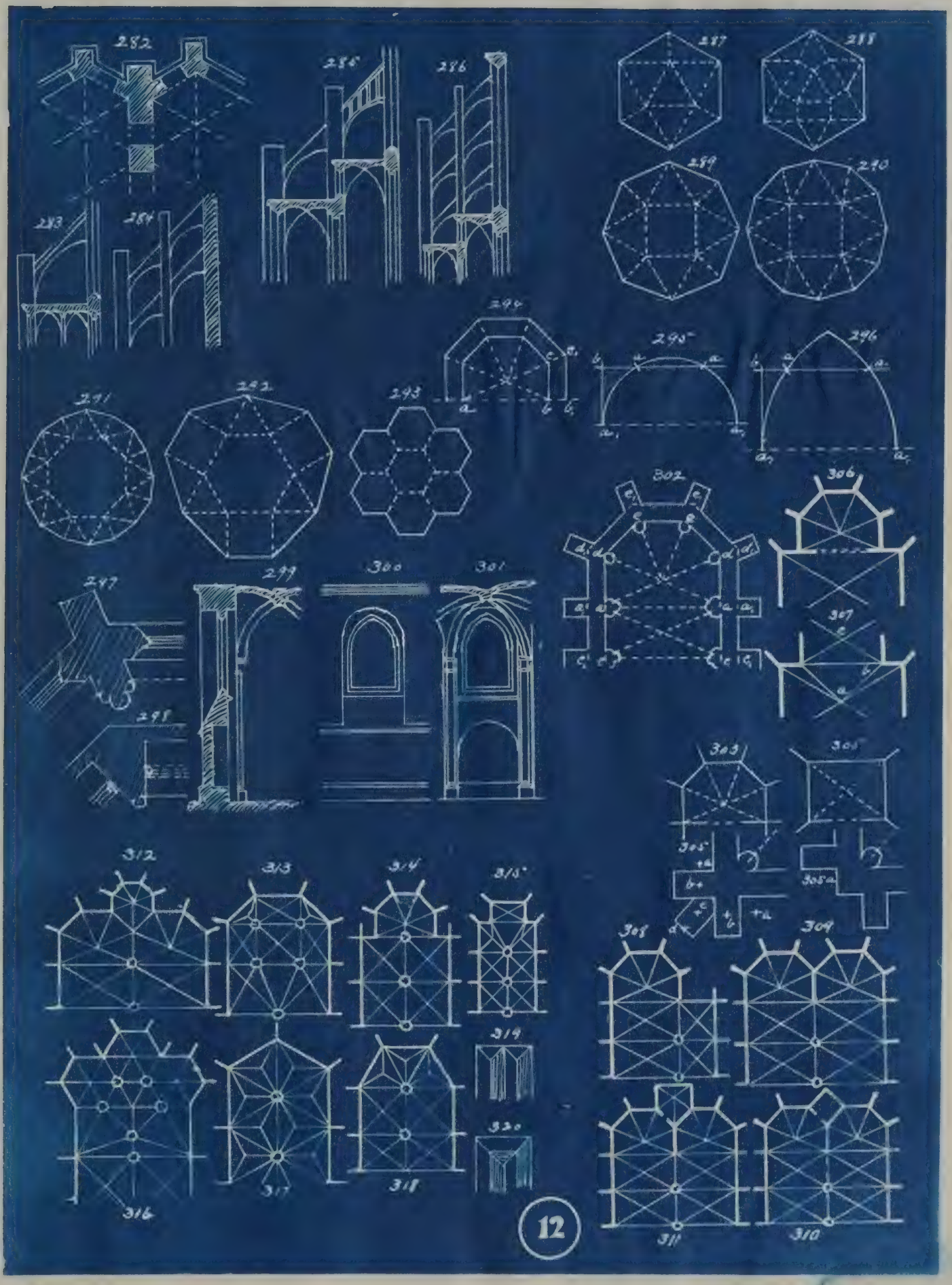
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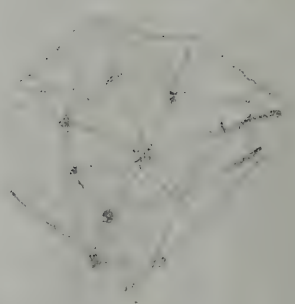

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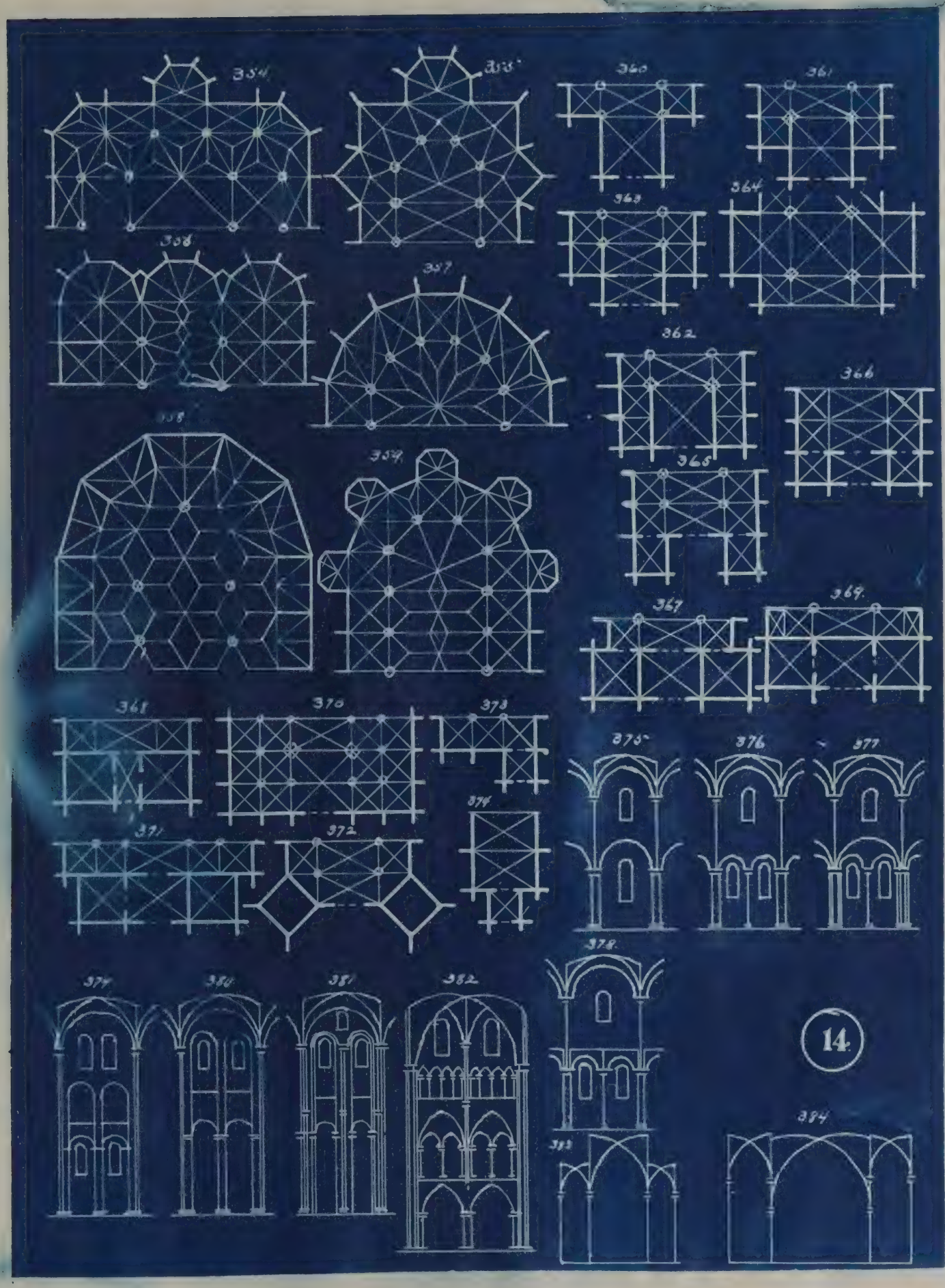
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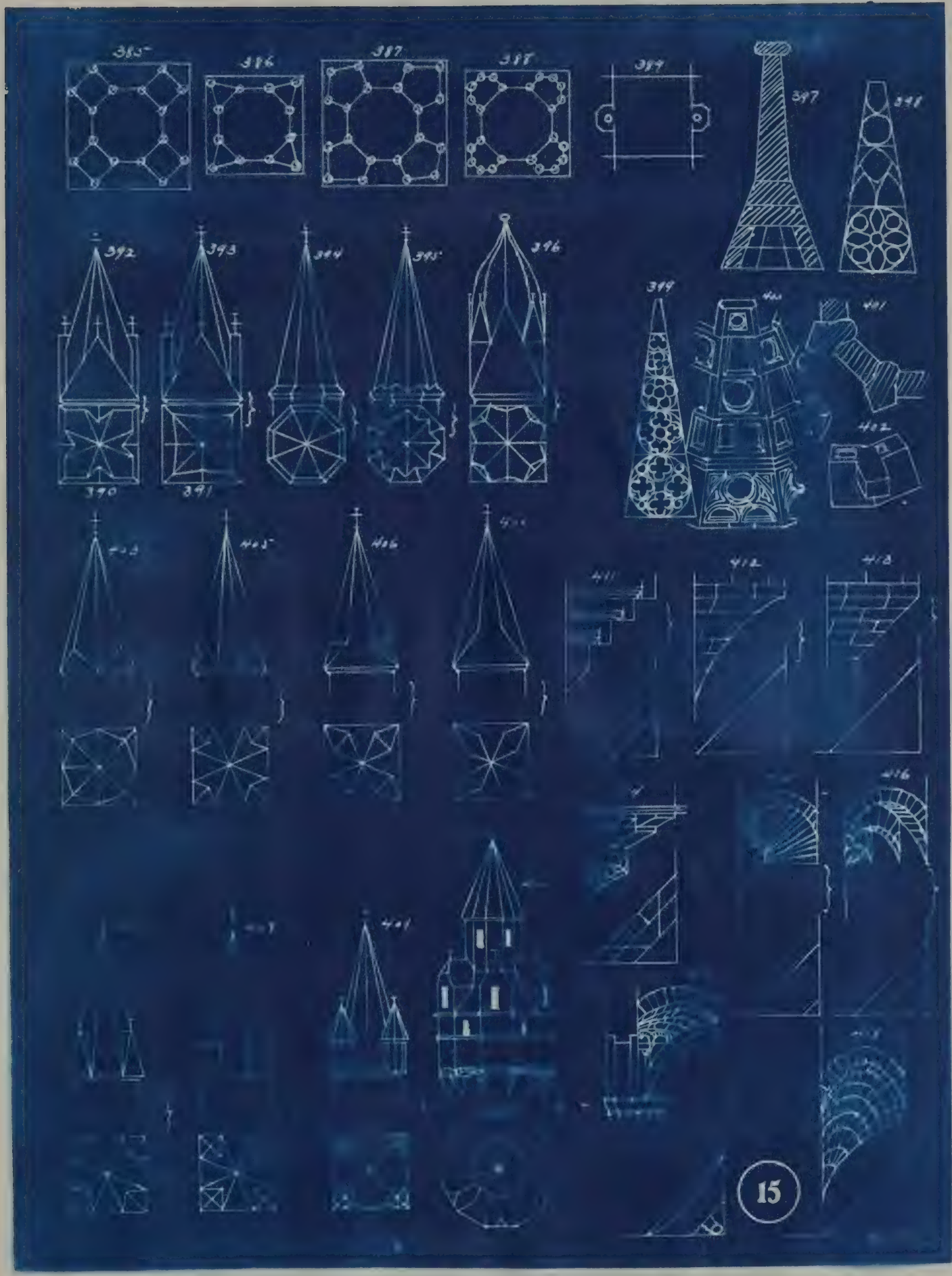
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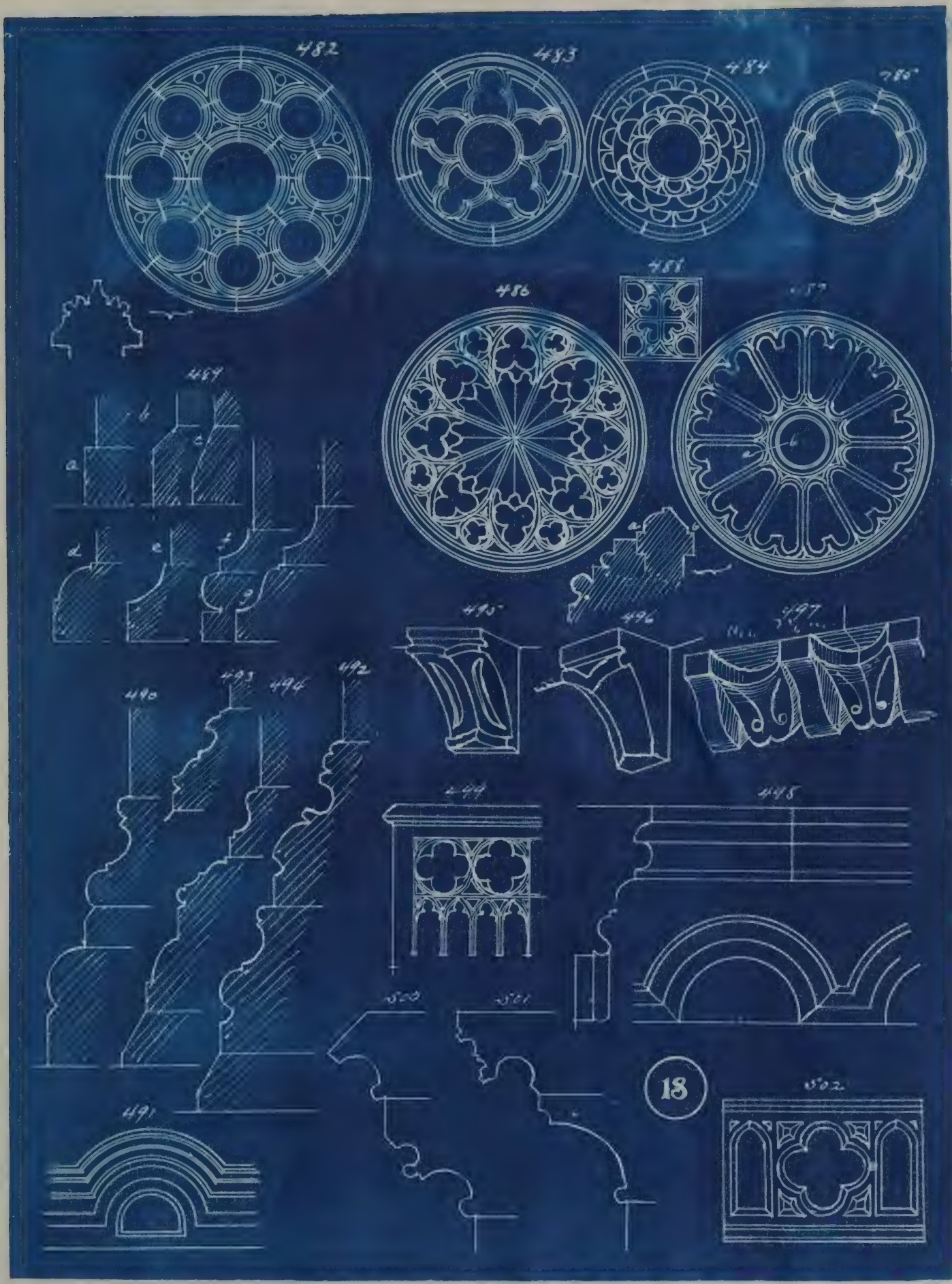
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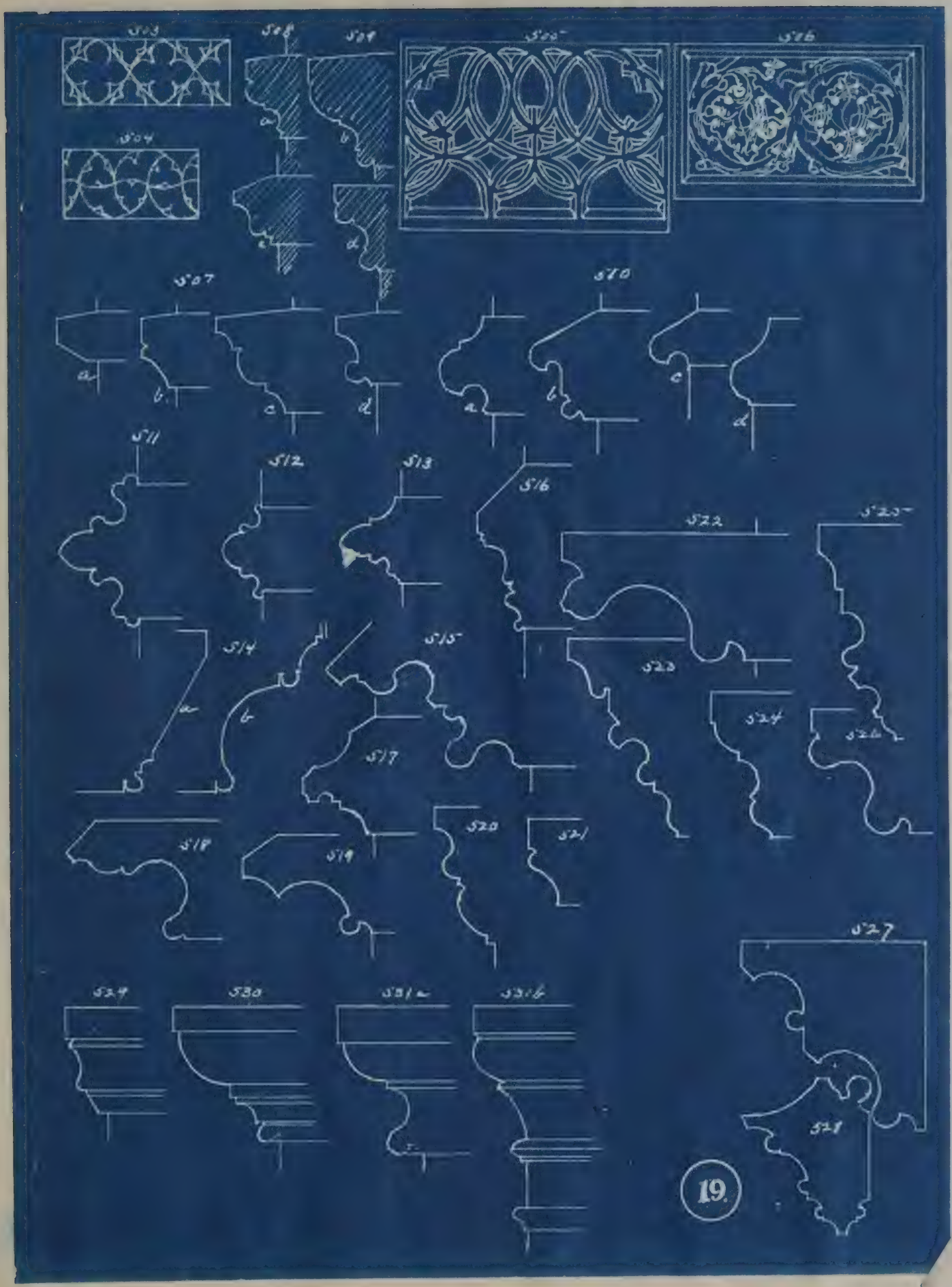
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Taf. III.

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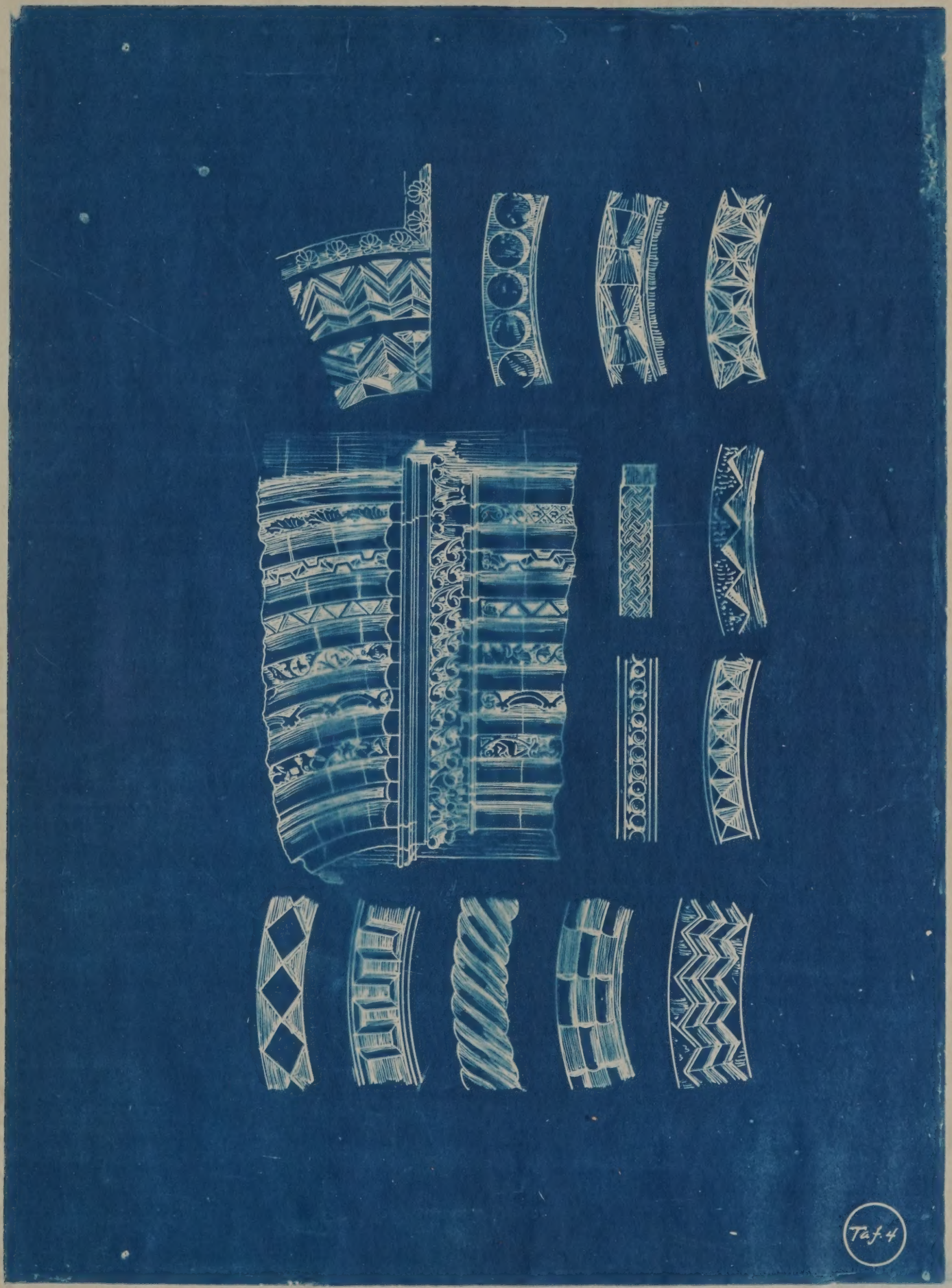

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